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NASA/MSFC FY-83 Atmospheric Processes Research Review

ORIGINAL

*Summary of a program review held at
Huntsville, Alabama
May 24-25, 1983*



25th Anniversary
1958-1983

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NASA/MSFC FY-83 Atmospheric Processes Research Review

*Compiled by
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Marshall Space Flight Center, Alabama*

**Summary of a program review held at
Huntsville, Alabama
May 24-25, 1983**

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ACKNOWLEDGMENTS

The productive inputs from the investigators in the Atmospheric Processes Research Review contributed very much to the success of the review. This report provides the opportunity for everyone to become better acquainted with the work of other investigators and to see how the research relates to the overall objective of NASA's Atmospheric Processes Research Program. Appreciation is expressed to all those who provided inputs to the review. The organizers trust that the inputs will provide a better frame of reference from which to proceed with the next year's research activities.

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PREFACE

Each year NASA supports research in various disciplinary program areas. The coordination and exchange of information among those sponsored by NASA to conduct research studies are important elements of each program. The Office of Space Science and Applications, Earth Science and Applications Division, via Announcements of Opportunity (AO), Application Notices (AN), etc., invites interested investigators throughout the country to communicate their research ideas for consideration. The proposals in the Atmospheric Processes Research area selected and assigned to the NASA Marshall Space Flight Center's (MSFC's) Atmospheric Sciences Division for technical monitorship, together with the research efforts included in the FY-84 MSFC Research and Technology Operating Plan (RTOP), are the source of principal focus for the NASA/MSFC FY-83 Atmospheric Processes Research Review.

The principal purpose of the review and summary report is to provide those having major research activities sponsored by NASA on atmospheric research and assigned to MSFC's Atmospheric Sciences Division an opportunity to present their accomplishments and future plans. In addition, the review provides NASA Headquarters and MSFC Research Managers with a current status report plus suggestions for future research to use in developing the program. To assist us in preparing the report, each investigator was requested to submit the technical aspects of their research efforts. The principal managers involved are Mr. John Theon, Dr. James Dodge, and Dr. Robert Curran, Atmospheric Dynamics and Radiation Branch, Earth Science and Applications Division, OSSA, and Dr. William W. Vaughan, Atmospheric Sciences Division, Systems Dynamics Laboratory, MSFC. Dr. Robert Turner serves as the coordinator for the research review.

Five general areas of NASA's Atmospheric Research Program which were included in the review are: Global Atmospheric Processes Activities; Doppler Lidar Wind Research Activities; Mesoscale Atmospheric Processes Research Activities; Solar - Upper/Lower Atmospheric Coupling Research; and Lightning Research Program Activities. The technical aspects of the research efforts are stressed to provide the rationale for recommendations on the coming year's research.

The organizers endeavored to make this report a review of the major aspects of the sponsored research activities relative to the NASA program aims. The review report was planned to permit the maximum exchange of information.

It was recognized that the scopes of individual research efforts comprise a wide range. Some are very modest or have been under way for only a short period of time, whereas others involve several years of activity. However, the opportunity to learn what each investigator is doing and to develop the team relationship necessary for a meaningful research program were considered most important. It is toward this goal that this summary report has been developed.

Recipients of this report on the NASA/MSFC FY-83 Atmospheric Processes Research Review are encouraged to communicate directly with the respective principal investigators regarding scientific and technical matters or questions they might have on the research efforts. Any recommendations or suggestions concerning the program will be welcomed.

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GLOBAL SCALE PROCESSES RESEARCH

APPLICATION OF SATELLITE DATA TO STUDY EFFECTS OF LATENT HEAT RELEASE ON CYCLONES

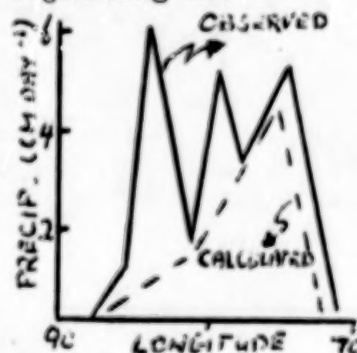
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MOTIVATION AND GOALS OF THE RESEARCH

When we formulated the initial work plan, we decided that in many cyclonic systems, especially the statically stable mid-winter type, the dominant mode of latent heating is associated with slow uplift on the scale of the cyclone. We concluded that in spite of the evidence of instances of mesoscale organization of, say, warm frontal precipitation, most precipitation was the stable cyclonic-scale type. The publications by Tang and Fichtl (1983a, 1983b) and Clark, Staver, and Hsie (1983) investigate the effects of this heating on synoptic scale systems at mid-latitudes.

Our thinking as to the role of mesoscale processes in organizing and possibly enhancing latent heating even in the stable wintertime cyclones has changed. Fig. 1 from Clark et al. (1983) illustrates the problem we are faced with. It compares precipitation rates calculated with a quasi-geostrophic diagnostic model for a March, 1978 storm with observations. Clearly, the quasi-geostrophic results account for, at best, the steady background precipitation but come nowhere near the large peaks which are so highly suggestive of strong mesoscale organization of the precipitation and vertical motion fields.



The working premise of FY83 and E4 work is that for most cyclonic systems at mid-latitudes mesoscale organization and enhancement of latent heat release is an important factor which must be accounted for to obtain a comprehensive understanding of the implications of latent heating on the storm.

ACCOMPLISHMENTS IN FISCAL 1983

We have completed a detailed diagnostic study of latent heating effects on the March 20-25 storm of 1978 to appear in Clark, Hsie, and Staver (1983). The ageostrophic circulation and associated vertical motion field at each map time were calculated using quasi- and semi-geostrophic formulations of the equations appropriate to synoptic scale systems. The latter formulation is more general of the two in that it permits advection of geostrophic momentum and heat by the ageostrophic as well as geostrophic winds whereas the former only allows the geostrophic advection. The model included 12 levels from the ground to 200 mb and covered most of the eastern USA. Wave energy was forced

to decay with height above 200 mb and horizontal gradients of vertical motion at the lateral boundary were set to zero. Orography and Ekman pumping were allowed for the lowest level and latent heating was accounted for by modifying the lapse rates to be moist adiabatic in areas where we expected upward motion and latent heating to occur from satellite and surface observations. Actual average lapse rates in areas of broad upward motion need not be moist adiabatic but are usually somewhere between the moist and dry rates. Thus, we could overestimate the latent heating by up to 25%. For most days of the storm, the quasi- and semi-geostrophic calculations can account for the background steady component of the observed precipitation but they miss by a factor of two or three the peaks that occur in the spatial and temporal distribution of rainfall.

We then used our diagnosed ageostrophic winds and associated vertical motions as well as the observed geostrophic winds, temperatures, and tendencies of vorticity and temperature to evaluate subsynoptic effects as residuals in horizontally averaged enstrophy and available potential energy equations. The residuals follow interesting and coherent patterns in the developing and mature stages of the storm and are highly suggestive of the important role that subsynoptic or mesoscale motions play in the storm evolution.

The studies by Tang and Fichtl (1983a, 1983b) were theoretical attempts to examine the effect of stable latent heat release on baroclinically unstable waves. They found that the direct generation of wave energy by latent heating was small but the implications of the induced alterations of wave structure on the energetics were profound.

Xu and Clark (1983) developed a modified wave CISK theory that could be applied to mesoscale convective systems at mid-latitudes. No such theory previously been formulated to explain convective rainbands in an environment with little or no shear for the disturbances to feed upon - a situation often found in warm frontal precipitation. We modified traditional wave CISK theory by:

- i. allowing for an internally determined time-lag between convection and mesoscale forcing through boundary-layer mass convergence;
- ii. permitting the convective clouds to actively grow and decay in response to mesoscale forcing and bulk dissipation.

The structure of the resulting most rapidly growing waves bears a strong resemblance to observed disturbances. Furthermore, the e-folding time of the growing waves is comparable to the lifetime of mesoscale convective disturbances.

CURRENT FOCUS AND PLANS FOR FISCAL YEAR 1984

1. Continued Theoretical Studies. We plan to expand our wave-CISK model in a baroclinic atmosphere by accounting for nonlinear mixing due to cloud mass fluxes. This will make our model more applicable to background fields conducive to rainstorms and even mature storms. A first tentative step has

been taken in this direction and the results are promising. Our meso-wave-CISK model works well in the case of (moderate) symmetric baroclinity and the newly discovered scale selection mechanism yields structures that compare well with observations. This gives us more confidence to further our research at least in the following areas:

- i. We will use our modified cloud and meso-wave-CISK model in a background flow with parallel (large scale) shear and examine, theoretically, the response of meso-wave-CISK to both symmetric and near symmetric disturbances (using asymptotic methods). The dependence of the growth rates of meso-wave-CISK on the Richardson number of background flow and the dynamical structure of the most unstable waves will allow us to test our theory more closely against observations (see later), and also will possibly help us to understand both the interaction of cumulus convection and mesoscale and the interaction of mesoscale circulations with larger scales. Very little is known about the later, although "The latter areas appear to be ripe for theoretical analysis" - NSP, 1982.
- ii. The present meso-wave-CISK model only allows for cloud heating/cooling linearly. Thus, it is not appropriate to the matured MCS (Mesoscale convective system). As rainstorms grow to matured stage, the convection of cumulus clouds becomes so intense that the vertical mesoscale momentum transport processed by the cloud mass flux becomes dominant in the horizontal momentum equations. Thus, the momentum transport terms are essentially nonlinear and very likely dominant over other nonlinear terms. Thus, the primary nonlinear consideration in the next step will be to parameterize the cloud mass fluxes in the momentum equations. The nonlinearity will render the exponentially growing (linear unstable) mode a finite-amplitude mode, which will (possibly) be an appropriate representation of (theoretically) a matured MCS.

2. Extended theoretical studies: Conditional Symmetric Instability.

According to observations of the MCS and frontal rainbands they can be divided into two classes according to their propagation properties: I. quasi-steady convective bands drifting approximately with mean wind, such as warm frontal rainbands; II. propagating (relative to the mean wind) bands, such as warm-sector rainbands or squall lines. As we discussed in Xu and Clark (1983), it is easy to see from the extended Miles's theorem (Bolton, 1980) that propagating and growing waves can be generated by a heating which is somewhat out of phase with the upward motion at some height; however, a monotonically growing perturbation only happens when the heating is in phase with the upward motion at all levels. Thus, the difference between the two classes, i.e., above I and II, most likely implies different cloud heating regimes. We will refer to them as regime I and regime II respectively.

In view of the above considerations and also for the purpose of the application of our theoretical results, we have to construct a theoretical mesoscale circulation model with heating regime I: the first coming to mind is the circulation of CSI. Fortunately, the mathematical feasibility for further analytical work on the theory of CSI is suggested by our recent studies.

3. Comparison of Theory with Satellite and Conventional Observations. Mesoscale meteorology, like many sciences, suffers from a lack of interaction among observational, experimental and theoretical studies. Field experiments often suffer from a deficiency of testable hypotheses provided by models and theories, while theoretical studies often wander into unproductive abstraction due to ignorance of the actual data. Now, the time for the conjunction of these approaches appears to be ripe and urgently needed. As the first step in this direction, we are planning to do the following:

- i. Analyze the spatial structure of warm sector cumulus cloud bands from high resolution satellite data (both the hardware and software are available in Penn State), i.e., calculate the 1-D or 2-D time-dependent spatial spectra of satellite-derived cloud heights. Also Penn State is going to have the responsibility of collecting and analyzing digital radar precipitation data from the radar network coverage most of the USA. Thus, we will be able to combine satellite, radar and surface observations to obtain information about convection and precipitation in warm frontal areas.
- ii. Analyze and calculate mean dry and moist stratifications, wind shears, and other necessary background field parameters from synoptic data for the corresponding cases and areas. Input these parameters into theoretical models, calculate the growth rate spectra (linear models), or time dependent amplitude spectra (nonlinear models).

We also believe that the combination of satellite data provided by VAS (Visible Infrared Spin-Scan Radiometer Atmospheric Sounder) onboard GOES and radar data provides an unprecedented opportunity to investigate mesoscale convective systems.

We plan to use the above data in combination with regular synoptic radiosondes to study the relationship between large (meso and synoptic) scale moisture convergence, the moisture supply in the PBL, and the intensity of convection and the concomitant precipitation efficiency of cloud ensembles in a number of selected cases. Previous studies of moisture budgets for convective systems (Fritsch et al., 1976 and Cooper and Garstang, 1982) indicate that the moisture processed by the clouds is many times larger than the large-scale moisture convergence. Also Fritsch et al. (1976) found that only 60% of the observed precipitation could be accounted for from the large-scale moisture convergence and the depletion of the available PBL moisture.

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TITLE: Application of Satellite Data to Tropic/Subtropic Moisture Coupling

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SIGNIFICANT ACCOMPLISHMENTS FY83:

The following summarizes the status of the project, covering the first two weeks for which the project has been funded. (Funding received in April 1983).

Introduction: At times, vast quantities of upper tropospheric moisture emanate from the ITCZ, either from tropical disturbances along it or in conjunction with southward moving cold fronts in the central Pacific. These bursts of moisture move with high speed, sometimes even from south of the equator, northeastwards, and are often associated with storm activity in the southern portion of the United States. The special data platforms of the FGGE special observing periods in 1979 allow a detailed study of this phenomenon. In conjunction with GOES-west and TIROS-N satellite products, without which a study of this tropical region would not be feasible, these special FGGE data sets are being examined to:

- i) Describe the moisture burst as a synoptic weather phenomenon and its interaction with midlatitude meteorology;
- ii) Assess the degree to which fields of satellite data may be utilized in studying synoptic systems in data-sparse regions;
- iii) Improve our understanding of the general circulation of the tropical eastern Pacific Ocean region.

Current Status: The effort to date has been restricted to literature search, data acquisition and task definition. In addition to the wealth of FGGE meetings and operations reports which describe data platforms, procedures, availability and quality, and preliminary data analysis, a bibliography of approximately 100 citations on specific topics has been prepared. These topics include methods of data analysis (including procedures for implementing the McIDAS machine), tropical synoptic and climatological studies (Therpenier and Cruette, 1979, for example, describe possible consequences of the moisture burst phenomenon over the United States), modelling efforts (of which there are almost none), and satellite data quality (which is essentially restricted to single sounding analysis and investigation of meso-scale systems).

The following summarizes the FGGE data sources and their availability. Although the merged FGGE data set is available on finely gridded fields (1 7/8° lat/lon grid), our study requires the gridding of data by platform (satellite, surface observations, rawin- and drop-sonde, etc.). The analysis

domain will be from 10°S to 30°N and from approximately 160°W to the west coast of North America. The FGGE Operations Report (Vol. 3, 1981) summarizes data availability as follows (based on the period 16-25 January 1979):

8) Surface observations, including ships, drifting bouys, and surface synoptic stations: South of the equator, about 1 observation per day is available per 5x5 lat/lon square, with a concentration in the vicinity of FGGE scientific ships. North of the equator, observation frequency increases northward, from about 1 observation per 3 days at the equator, to between 2 and 5 observations per day at 30°N, both for 5° lat/lon squares.

ii) Traditional upper air soundings: From 10°S to 20°N, about one sounding every two days is available per 5° square. The data are primarily dropsonde and are more frequent in the latter part of January. The distribution is fairly uniform and will be adequate for comparison with satellite observations.

iii) Satellite soundings (TIROS-N): For the entire domain, 2-5 soundings per day are available for each 5° square. The quality of the moisture soundings is uncertain and unavailable before 22 January. Although TIROS-N did not become operational until March 1, raw data was archived and later fed through the operational data system.

iv) Satellite winds: South of 1°N about 10 observations/day are available per 5° square, whereas, 3-5 observations per day typify regions to the north.

v) Isolated constant level observations, including AIREPS and balloon data: These data are highly variable and will generally have to be used as corroborative data. In the deep tropics 0.5 to 4 observations per day are available, with an order of magnitude increase north of 20°N. The region east of 140° west is almost devoid of these observations.

CURRENT FOCUS OF RESEARCH

We have tentatively identified two winter case-study periods from satellite film loops prepared by the Walter A. Bohan Co. These three-day periods run concurrently from January 20 to January 26, 1979. The two moisture bursts occurring during this period were the most typical observed during the FGGE intensive period. Additionally, we can observe the ultimate fate of the first burst as it moved across the south central United States. A summer case has not yet been identified. Of the weak disturbances which existed during the period of intensive data gathering, further study is needed to decide which is most typical. Data acquisition and development of analysis procedures are currently under way.

We are assembling a climatology of typical moisture burst parameters, including frequency, duration, preferred location, and associated circulation for several typical winter and summer periods from archived GOES-west infrared and visible imagery at Texas A&M. This study will give perspective to the detailed case studies.

Visualization techniques are being developed in conjunction with the McIDAS terminal at Marshall and also with the Climate Group at NCAR. Chervin has agreed to make his 14-reel film loops depicting the FGGE analysis available. These tools will be of considerable use in evaluating data subsets.

PLANS FOR FY84:

Once the data is acquired, case studies of the two winter periods and one summer period will be prepared. Much of the activity will be centered around preparing, comparing, and evaluating the data, not in terms of the quality and accuracy of individual observations, but in terms of its usefulness in describing large-scale synoptic fields. The one exception to this statement may be the question of moisture distribution, for the simple reason that this satellite observation has not yet reached operational status.

RECOMMENDATIONS FOR NEW RESEARCH:

At the two week point in our current research, we feel recommendations are premature.

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VARIATIONAL ANALYSIS WITH SATELLITE DATA PROJECT
(VASP)

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-83

The significant accomplishments for the VASP project, which has been underway for 8 months, centers around theoretical developments and data preparation for the first of two variational objective analysis methods being developed for the quantitative meshing of remotely sensed TIROS-N (and eventually VAS) temperature and height data with data from conventional immersion techniques.

The theoretical work on this project began with a reassessment of the equations presented in the original proposal with a view of incorporating the reviewer's comments. The assessments were extended to past Achtemeier papers and reports, this work done with the aid of Ms. Elaine Chandler (Ph.D. Mathematics) who was brought on as a consultant at no cost to the project. These reviews have confirmed that the variational approaches to be used are mathematically sound.

Other theoretical work has concentrated on three subjects that will determine the final formulations for the variational models. These are: the new nonlinear vertical coordinate, the formulation for the explicitly represented local tendencies of the wind velocity and temperature, and the means to require simultaneous pointwise and grid column mass continuity. As a result of this theoretical work, the nonlinear vertical coordinate originally proposed has been replaced with a new nonlinear vertical coordinate that is constructed from two curves that are piecewise continuous through their second derivatives. The new nonlinear vertical coordinate allows the user to better control which sigma surfaces are to become parallel with the pressure surfaces. It is also possible to make the coordinate surfaces parallel at levels much lower in the troposphere than was possible with the original formulation.

An independent, explicit measure of the tendencies of wind velocity and temperature was developed with the following approach. The tendencies were expanded in series form and truncated before the second and higher derivatives. The remaining coefficient was partitioned into advective and developmental contributions. The advective contribution will be obtained by a barotropic advective current method similar to the technique proposed by Fjortoft three decades ago. This approach allows the tendencies to be treated as independent variables and each will be assigned a relative weight in the variational formulations.

The discovery of a methodology to include integral constraints into the variational formulation is one of the most significant accomplishments to date. This solves the last problem that determines the final formulation for the variational models; the problem of insuring both pointwise and grid column mass continuity within the analysis domain.

FOCUS OF CURRENT RESEARCH ACTIVITIES

The current research activities center around three areas. The first, and primary research area, is the development of the Euler-Lagrange equations that comprise the first variational model. This model includes the two horizontal momentum equations, the hydrostatic equation and the equation for the conservation of mass. These equations have been transformed into the coordinate system that includes the nonlinear vertical coordinate. The E-L equations have been derived, the terms arranged, and the equations ordered into the solution sequence. Subsidiary equations such as the Lambert conformal map transformations are also being expanded so that the Model 1 equations can be put into finite differences.

The second research area has centered around obtaining insights into the workings of the integral constraint. A small variational vertical model was developed. (It is an integral form of O'Brien's vertical velocity adjustment method.) The resultant adjustment equation takes the form of a convergent Helmholtz equation when the vertical velocity is approximately measured. It reduces to a simple Poisson equation in the Lagrangian multiplier when the vertical velocity is assigned. A physically consistent set of boundary conditions have been developed for this equation.

The third research area has centered around development of several ways to include approximations to the vorticity equation in the calculation of kinematic vertical velocities. It is hypothesized that a variational approach which includes both the divergence and the vorticity of the observed wind will give better approximations to the vertical velocity than the divergence of the observed wind taken alone.

These last two research areas compliment the first in that computer programs will be used as part of the first research area. This is in keeping with the approach that the general variational problem should be broken into smaller components and the solution built up from these.

PLANS FOR FY-84

The plans for 1984 include the completion of the finite differencing and the coding of Model 1. The model will be run and debugged with AVE data sets (SESAME 1 data) and TIROS-N data. The performance of the model will be evaluated with a diagnostic study. A number of other studies that utilize SESAME 1 data have already been done by other researchers. These studies can be used as independent sources for verification of the variational model.

LIST OF PUBLICATIONS

Variational Analysis for a Limited Area Windfield. To be submitted to Journal of Climatology and Applied Meteorology. (Partial support from VASP project.)

TITLE: Utilization of Satellite Cloud Information to Diagnose the Energy State and Transformations in Extratropical Cyclones

RESEARCH INVESTIGATOR:

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Tel. (31.) 494-3286

SIGNIFICANT ACCOMPLISHMENTS:

The work during this past six months has focused on:

- (1) completion of heating calculations and a sensitivity study simulating the effect of satellite data in recovering diabatic heating rates in data sparse areas,
- (2) calculation of available potential energy generation using original and satellite-modified latent heating calculations and,
- (3) preparation of a paper for the preprint volume and presentation at the Sixth Conference on Numerical Weather Prediction, June 6-9, 1983, Omaha, Nebraska.

CURRENT FOCUS OF RESEARCH:

Current research focuses on partitioning ω into adiabatic and non-adiabatic components as a device for further testing impact of the satellite modification scheme and for examination of the role of latent heat release. We are also finishing the tests of the basic modification scheme applied to the Jan 75 case and impact on generation of APE.

PLANS FOR FY84:

We will be completing APE budget for Jan 75 case using modified latent heat release, and analyzing impact of latent heat release. We will repeat a test of the modification scheme on SESAME I data period. Data already accumulated and gridded. We will also be selecting one or two other cases for future analyses.

FUTURE RESEARCH:

Much remains to be done to evaluate the role of latent heat release in extratropical cyclone development. The uniquely comprehensive view of moisture fields suggests that satellite data will be useful in this evaluation. In particular, satellite data have great potential for enhancing temperature/moisture analyses. In order to test the impact of these enhancements, it would be useful to perform forecast experiments, coupled with a full range of kinematic and energetic diagnoses, using a moisture/latent heat sensitive model, such as the Drexel University LAMPS model.

PUBLICATIONS:

Kenney, S. E., & P. J. Smith, 1983: On the release of eddy available potential energy in an extratropical cyclone system. MWR, 111, in press.

Dare, P. M. & P. J. Smith, 1983: A comparison of observed and numerically predicted eddy kinetic energy budgets for a developing extratropical cyclone. Preprints of the Sixth Conference on Numerical Weather Prediction, June 6-9, 1983, Omaha, Nebraska.

TITLE: Use of Satellite Data in a Diagnostic Parameterization of Convective Heating

RESEARCH INVESTIGATOR:

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Universities Space Research Association
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(205) 453-1944

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-83:

1. Diagnostic Heating Calculations

The first half of FY-83 has been spent completing model diagnosed diabatic heating and moistening of the atmospheric environment during AVE/SESAME I. The computations were performed for 10 APR 1800 GMT through 11 APR 0300 GMT. A schematic diagram of the diagnostic model is shown in the accompanying figure. The most significant aspects of the findings can be summarized as follows: Cumulus-scale mass flux constitutes a sizeable fraction of the total grid-scale (subsynoptic-scale) mass flux. In fact, at 2100 GMT the areal mean updraft mass flux exceeds the gridscale upward motion which suggests the importance of organized dynamical processes at a scale smaller than can be resolved with the SESAME rawinsonde network. Using information from the cumulus scale water budget to obtain mass flux estimates it has been determined that convective precipitation efficiency is a major controlling influence on the shape of the cumulus mass flux profile. Net diabatic heating from condensation and evaporation in the SESAME network has a more complex vertical distribution than is commonly obtained from Kuo-type diagnostic methods. Maximum heating is found at mid-tropospheric levels except at 2100 GMT when it peaks at 250 mb. Stratospheric cooling is diagnosed from overshooting cloud tops. Use of digital IR data to define areal distributions of convective cloud tops is a viable method of diagnostic parameterization closure when combined with observed rainfall rate.

2. Atmospheric Energetics

A reformulation of the pressure coordinate version of the available potential energy (APE) equation has been derived which offers two significant advantages. This new version no longer requires explicit evaluation of the reference state tendency, dPr/dt . As a result, the computations are more reliable and a clearer representation of boundary work, generation of kinetic energy and changes in APE is obtained.

CURRENT FOCUS OF RESEARCH:

Current emphasis is on completing APE budget calculations for SESAME which utilize the diagnosed heating estimates and the recently derived version of the APE equation.

PLANS FOR FY-83/84:

The remainder of FY-83 will be given to repeating calculations for the JAN '75 cyclone case currently being studied by Purdue University. A third case study is also to be performed in conjunction with the Illinois State Water Survey.

RECOMMENDATIONS FOR NEW RESEARCH:

An application of the diagnostic parameterization to a portion of the FGGE IIb data set is planned to begin in late FY-83. There is a need to incorporate remotely sensed rainfall into the scheme to supplement observed precipitation.

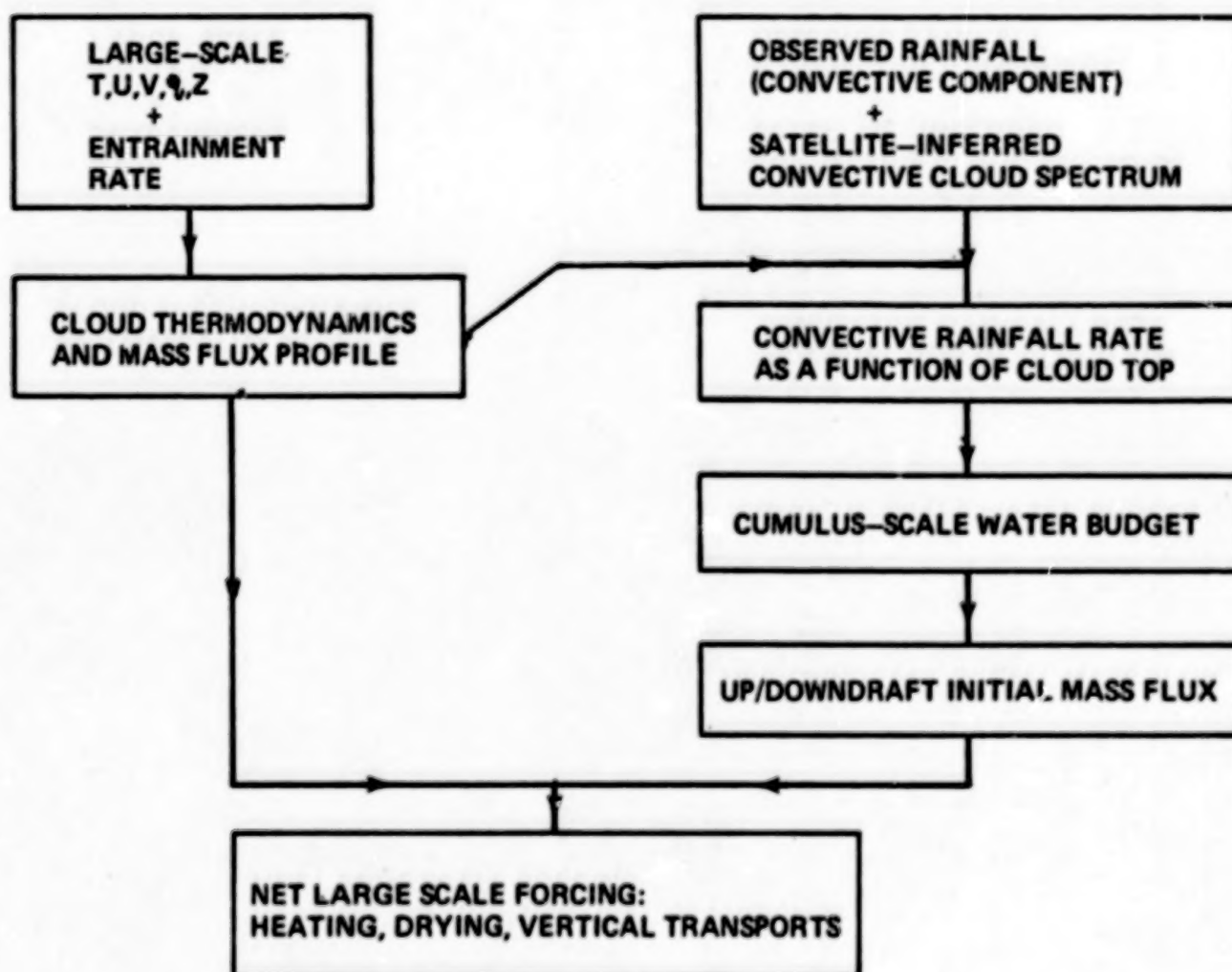
PUBLICATIONS AND PRESENTATIONS:

Robertson, F. R. and P. J. Smith, 1983: The impact of model moist processes on the energetics of extratropical cyclones. Mon. Wea. Rev., 111, 1-22.

Robertson, F. R., 1983: Reference pressure change and the available potential energy of open systems. Submitted to Tellus.

Robertson, F. R., 1983: Diagnosis of convective heating and mass transport during AVE/SESAME I. Manuscript.

DIAGNOSTIC CUMULUS PARAMETERIZATION MODEL



TITLE: Dynamics and Energetics of the South Pacific Convergence Zone During FGGE SOP-1

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS:

Since the contract is not yet funded only preliminary data gathering activities have been conducted. FGGE IIIB data for the South Pacific have been secured. We have also arranged for acquiring Nimbus/SMMR data for rainfall estimates.

CURRENT FOCUS OF RESEARCH:

Present emphasis is on studying existing algorithms for obtaining rainfall rates from SMMR microwave radiances and how a characterization of the field-of-view using infrared radiances from GOES West might enhance the accuracy of rainfall estimates.

PLANS FOR FY-84:

- 1) The first task planned for this year is to obtain a best estimate and error bounds for precipitation over the South Pacific during SOP-1. Moisture budget, microwave and infrared estimates will be derived.
- 2) Derived rainfall will be utilized as input to a diagnostic cumulus parameterization scheme to derive diabatic heating in the South Pacific Convergence Zone arising from convective processes.
- 3) Gridded fields of data for the region 10°N to 60°S at all longitudes will be obtained at NMC for use in FY-85/86.

PUBLICATIONS:

Vincent, D. G. 1982: Circulation features over the South Pacific during 10-18 January 1979. Mon. Wea. Rev., 110, 773-787.

CAUSES AND PREDICTION OF ZONAL WIND INTENSITY VARIATIONS

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MOTIVATION AND GOALS OF THE RESEARCH

The goal of our research at Penn State is to combine the observational capabilities of satellite systems with dynamical knowledge and principles to obtain an enhanced capability for understanding and predicting the structure and evolution of global weather phenomena. Satellite technology encourages a global view of atmospheric events and structure, and there is some hope that global-scale processes might be predictable over longer time periods than are smaller-scale synoptic processes.

Our preliminary studies have indicated that these goals may be accomplished by focusing on the cyclic oscillations in the strength of the mean zonal component of the wind. These oscillations have been known as the index cycle and are associated with the blocking phenomena that are important in determining local weather.

ACCOMPLISHMENTS IN FISCAL YEAR 1983

The Penn State research program has produced interesting results in a number of areas:

1. Theoretical Studies of Index Oscillations. A two-layer quasi-geostrophic spectral model with spherical geometry has been developed to study zonal wavenumber transitions in the Rossby regime and the transition between the Hadley and Rossby regimes. Our motivation is to produce analytically index cycle vacillations and study their properties as topography, radiative heating and dissipation are varied. Such studies would point toward techniques that might allow us to predict index cycle variations from global satellite observations. We performed an experiment to increase the spectral resolution of the model and noted almost no change from the original model. Thus our confidence in the truncated model is enhanced. Finite-amplitude propagating planetary wave solutions were obtained in the Rossby regime. They were stable to disturbances of any east-west wavenumber. However, with weak dissipation the waves could become unstable and vacillating solutions very similar to the index oscillation quickly evolved. Baroclinic energy conversions drive the vacillation. Barotropic wave-mean flow interactions are precluded from the model.

INDEX: WINTER 74-75
00Z 500MB HEIGHT DATA (30N-60N)

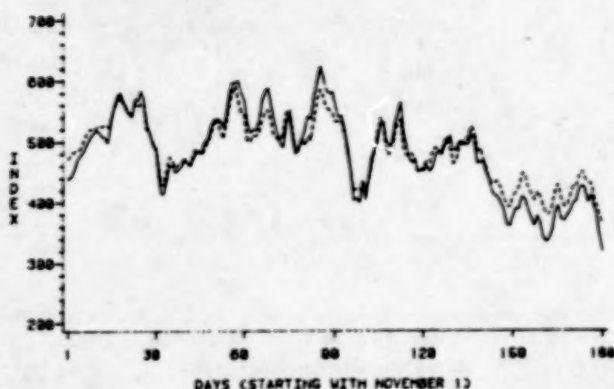


Fig. 1. Observed index (500 mb height difference 30N - 60N), solid line, as reproduced by 22-term empirical orthogonal expansion, broken line.



Fig. 2. Three-day forecast of 500 mb height field produced with 22-coefficient spectral model based on empirical orthogonal functions.

We also studied the evolution, with increasing heating, of a slightly different β -plane channel model and noted the evolution of the flow via a sequence of period doublings to an aperiodic state. We found that the presence of topography was indispensable to the index oscillations that evolved, see Clark (1983).

2. Modeling Index Cycle Variations. We are attempting to develop practical methods of utilizing global data fields to predict such phase independent quantities as zonal wind intensity. Our first attempts are based on quasi-geostrophic models, which could be initialized with global satellite temperature data. In this current period, Dr. Harry Henderson has completed programming and is now testing a first version of such a model based on a spectral decomposition utilizing empirical orthogonal functions to represent the height field.

The winter data from 1974-1977 was re-analyzed for the NMC octagonal grid, and it was found that more than the previously stated eight functions were needed to model the index oscillations. The additional functions were found by regression analysis of the observed index vs. the empirical coefficients. A total of about 20 functions seems to adequately represent the index series, (see Figure 1).

A barotropic model, which incorporates some effects of horizontal divergence, is being used to simulate and predict the index oscillations. The empirical functions are used as a filtering scheme - only selected functions important in index variations are used as basis functions. The numerical scheme uses a trapezoidal time integration method with 4th-order space differencing. A few long-term integrations have just been made, and it appears that nonlinear instability is affecting the results after about 16 days. The model runs smoothly to about seven days and then the results of aliasing errors begin to appear. An example of a three-day forecast is shown in Figure 2.

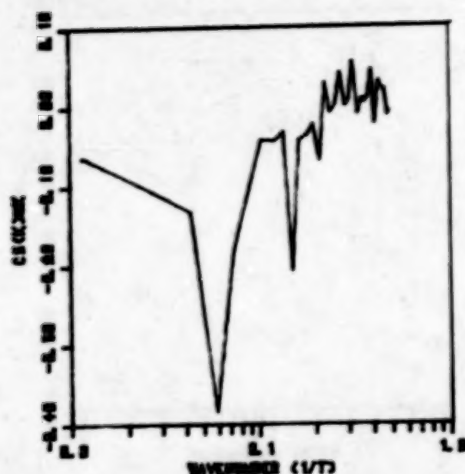


Fig. 3. Cospectrum of $\bar{U}_g(30^\circ - 45^\circ N)$ with $\bar{U}_g(60^\circ - 75^\circ N)$. Strong negative peak at 23-day period corresponds to index oscillation.

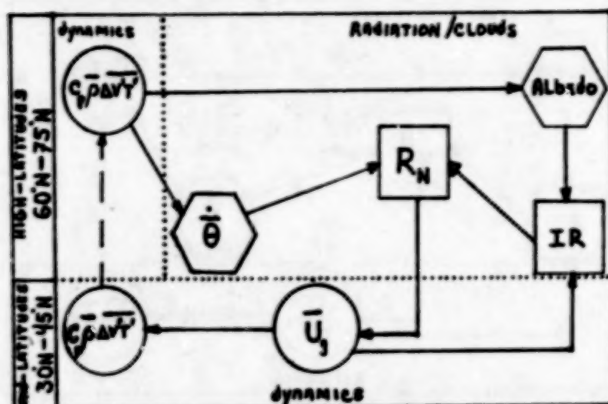


Fig. 4. Relationship between fields in 30° - 45°N and 60° - 75°N belts during index cycle.

Work is proceeding with the design of a filter to eliminate aliasing errors.

3. Observational Study of the Northern Hemisphere Index Oscillation. We have completed a study of the 20-25 day index oscillation using both TIROS Earth Radiation Budget (ERB) and conventional data. There are obvious spectral peaks in the 20-25 day range, not only in the zonal index and wave north-south heat and momentum transports, but also in cloud cover (especially at high latitudes), net solar heating, and infrared cooling, see Fig. 3. Our first task was to determine whether the oscillation was dynamically or diabatically driven. It appears that the former is the case, but radiative heating at high latitudes responding to albedo and cloud cover change positively feeds back on the index oscillation. Fig. 4 depicts the relationship of the various fields we have examined with a series of cross and co-spectral analyses. In summary \bar{U}_g leads meridional heat convergence, R_n , albedo, and $\bar{\theta}$, by about $\pi/2$ and lags IR by about $\pi/2$; IR leads the other thermal variables by $\pi/2$. We have also analyzed the dynamical processes responsible for the transfers of energy back and forth between the waves and the zonally-averaged flow. It is clear that barotropic conversion of energy between wave and mean kinetic energy is the prime driving force of the oscillation. Baroclinic conversions are small and not synchronized with the oscillation.

4. Cloud Streets as Remote Wind Indicators. Computer programs have been written allowing archiving of surface and upper air wind and temperature data for stations near significant cloud street occurrences. In addition, some high resolution (1 km) visible satellite pictures have been collected and archived.

The primary effort has been directed toward further development and study of a three-dimensional spectral model of moist convection embedded in a shearing, rotating environment. Including the Coriolis parameter is important here because cloud street outbreaks over warm oceanic regions in winter can last for days. Two-dimensional solutions develop in the three-dimensional model first, corresponding to the rolls first observed near

coastlines; these convective solutions first occur at a critical value of the vertical temperature gradient that depends on the wind speed at the top of the boundary layer, on the height of cloud base (surface dew-point temperature), and on the magnitude of the eddy viscosity.

Because the Coriolis parameter is included, we find that the orientation, horizontal wavelength, and smoothness of development of the rolls depends strongly on the ambient wind speed at the top of an Ekman boundary layer. For small wind speeds, the alignment of the rolls is approximately the same as the ambient wind direction at the top of the boundary layer, the wavelength of the rolls is about three times the boundary layer depth, and the development of the rolls is smooth. For large wind speeds, the alignment is about 25-30° to the left of the ambient wind direction, the wavelength is about four times the boundary layer depth, and the development of the rolls is sudden.

These results were presented at the Fourth Conference on Atmospheric and Oceanic Waves and Stability in March 1983.

CURRENT FOCUS AND PLANS FOR FISCAL YEAR 1984

1. Theoretical and Numerical Studies. Our observational study indicates that barotropic wave-mean flow energy conversions are crucial in driving the index oscillation. Yet our theoretical studies indicate that baroclinicity is necessary. We need to design a model that allows for both effects to determine which one is dominant.

We also wish to investigate another type of index oscillation observed in the atmosphere as well as the laboratory where the energy seems to oscillate back and forth between two distinct east-west wave-numbers. Mr. Feldstein is designing an experiment to study wave-wave vacillations in which the background mean flow is permitted to oscillate in such a way that alternately wavenumber n and m will become unstable and be allowed to grow.

2. Modeling Index Cycle Variations. The current focus is on developing suitable filtering techniques to control nonlinear instability in the prediction model. This will permit prediction runs for long periods and allow us to compare predicted zonal wind intensities with verification data. The model will then be augmented with both terrain and climatologically appropriate forcing. Terrain features provide an important control on the location and occurrence of blocking events (as is known from our theoretical results and work by others) and will be important in any successful model. A form of thermal forcing appropriate to wintertime conditions is evidently necessary as well.

3. Observational Study of the Northern Hemisphere Index Oscillation. It is imperative that our analysis be expanded into a truly global one. Level III b FGGE data sets are available on an approximately 2° x 2° latitude-longitude grid from GFDL and ECMWF. They span almost the entire year 1979. We plan to study the hemispheric properties of the index oscillation and contrast the southern one from its northern counterpart. If they should turn out to be synchronized with each other it will be interesting to analyze how they are coupled across the tropics. The interhemispheric propagation of

barotropic Rossby waves could be such a mechanism. But the mean zonal winds can strongly affect the direction and magnitude of the energy propagation. The FGGE data set will provide a unique opportunity to investigate this and other coupling mechanisms. Furthermore, global albedo, solar heating, and infrared cooling fields will aid us in investigating the positive feedback on the index oscillation induced by high-latitude albedo changes.

4. Cloud Streets as Remote Wind Indicators. For future theoretical work, the next important step will involve investigation of the stability of the rolls to three-dimensional disturbances. Latent heating effects significantly alter the stability of the rolls to two-dimensional disturbances and surely will be crucial toward explaining the commonly observed transition from rolls to cells. Parameterization techniques for including moisture in low-order models will be developed under joint sponsorship with the National Science Foundation.

One possible two-dimensional convective solution that has not been described by the present spectral model is that which develops when the ambient wind has an inflection point. These solutions are known to have different characteristic wavelengths and orientations than those associated with the present solutions. Hence to develop a usable boundary layer wind-measuring scheme, we must be able to discern both possibilities with a single model. Preliminary work in this area is planned in the next year.

PUBLICATIONS 1982-1983

Dutton, J. A. and Peter E. Kloeden, 1983: The existence of Hadley convective regimes of atmospheric motion. J. Austral. Math. Soc. Ser. B 24, 318-338.

Yost, D. A. and H. N. Shirer, 1982: Bifurcation and stability of low-order steady flows in horizontally and vertically forced convection. Journal of Atmospheric Sciences, 39, 114-125.

Shirer, H. N. and R. Wells, 1982: Improving spectral models by unfolding their singularities. Journal of Atmospheric Sciences, 39, 610-621.

Shirer, H. N., 1982: Toward a unified theory of atmospheric convective instability. Cloud Dynamics, E. M. Agee and T. Asai (eds.), D. Reidel Publishing Company, 163-177.

Henderson, H. W., 1982: A Numerical Study of the Global Axisymmetric Circulation with Varying Heating and Rotation Rates, Ph.D. dissertation, Department of Meteorology, The Pennsylvania State University, November 1982.

1983 (in press):

Shirer, H. N. and R. Wells: Mathematical Structure of the Singularities at the Transitions between Steady States in Hydrodynamic Systems. A volume in the series Lecture Notes in Physics, Springer-Verlag.

Submitted:

Clark, J. H. E.: The effect of Topography on the Evolution of Unstable Disturbances in a Baroclinic Atmosphere. J. Atmos. Sci.

In Preparation:

Feldstein, S. B. and J. H. E. Clark: The Hadley and Rossby Regimes on a Sphere. To be submitted to Mon. Wea. Rev.

Group-Kinetic Theory and Modeling of Atmospheric Turbulence

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I. Significant Accomplishments to Date in FY-83

A. Development of the Group-Kinetic Theory

The fluid turbulence is a nonlinear stochastic process whose micro-dynamical state is described by the Navier-Stokes equations of motions. A coarse-graining is necessary, but it involves a hierarchy of high order correlations. The closure currently in use is obtained by empirically modeling the many length scales and has no statistical mechanical basis. Therefore it does not derive transport properties and does not even recognize their existence in turbulence. The method is, however, superior to purely heuristic ones, such as were based upon the cutoffs by ∇^2 or ∇^4 that ignore all dynamical significance.

For initiating a statistical method of many bodies, a master equation must be found as our point of departure. This can be written in the form of the equation of evolution of the distribution function, as

$$(\partial_t + \underline{v} \cdot \underline{\nabla} + \underline{E} \cdot \underline{\partial}) f(t, \underline{x}, \underline{v}) = 0,$$

and can be shown to be equivalent to the above mentioned system of Navier-Stokes equation and the equation of continuity, by the use of the equivalence relation

$$f(t, \underline{x}, \underline{v}) = \delta[\underline{v} - \underline{u}(t, \underline{x})] .$$

Here $\underline{u}(t, \underline{x})$ is the fluid velocity function in the configurational space, and $f(t, \underline{x}, \underline{v})$ is the distribution function in the phase space, $\underline{E}(t, \underline{x})$ is a self-consistent field, including the pressure gradient, the buoyancy due to temperature and humidity fluctuations. The determination of the spectral structure, the turbulent transports and the various length scales requires a two-point distribution function $f(t', \underline{x}', \underline{v}'; t, \underline{x}, \underline{v})$ in conjunction with the one-point distribution function $f(t, \underline{x}, \underline{v})$. This method generates a kinetic hierarchy of high order distributions, in analogy with the BBGKY - hierarchy in plasma turbulence. The master equation presents the advantage that all nonlinearities arising from the velocity will disappear, since the velocity is now an independent variable, and that the master equation is homogeneous. Nevertheless, it is an enormous task of working with the two coupled distributions. This may be the reason why so little progress in statistical mechanics has been made for treating plasma and fluid turbulence.

In order to alleviate these difficulties, we develop a group-kinetic theory, abbreviated as "G-K theory", by adding the group-scaling to the kinetic theory, and by using the scaling operators A^0 and A' . The macro-group in the form

$$\underline{u}^0 = A^0 \underline{u}$$

or

$$f^0 = A^0 f$$

will furnish a cumulative spectral distribution $F(k)$, such that

$$\frac{1}{2} \langle \underline{u}^0{}^2 \rangle = \int_0^k dk' F(k') .$$

The closure is obtained statistically by exploiting the memory-loss. In this manner, a kinetic equation of f^0 will suffice for the determination of the spectral structure, and a transport theory can be formulated for the determination of all the Reynolds stresses and the transport coefficients.

The development of the group-kinetic theory and the method of closure have been discussed in details in the 4 Technical Reports of FY-82. They are simplified for applications in Technical Reports No. 1-5 of FY-83.

B. Group-Kinetic Theory of Turbulent Collective Collisions

Since turbulence is a collective phenomenon, the interaction among the eddies has a collective effect, as manifested in the collective collisions of eddies. The results are presented in Technical Reports No. 1 and 3.

C. Group-Kinetic Theory of Two-Dimensional Geostrophic Turbulence

The application of the G-K theory to the two-dimensional geostrophic turbulence finds the spectral laws k^{-4} and k^{-3} , with and without external force, respectively. The results are given in Technical Reports No. 2, and are compared with experimental results.

II. Focus of Current Research Activities

A. Comparison Between the Group-Kinetic Theory and Other Methods of Statistical Mechanics.

The Technical Report No. 4 is written for this purpose.

B. Group-Kinetic Theory of Shear Turbulence (Analytical Description)

The G-K theory is applied to shear turbulence and derives the spectral structure. See Technical Report No. 5. See also comparison with experiments in Figs. 1 and 2.

III. Plan for FY-84

- A. Spectral distribution and transport theory of turbulence in the stratified atmosphere with Coriolis force.
- B. Pressure-strain correlation in the stratified medium with a Coriolis force.
- C. Theory of spectral structure of stresses: fluxes of transport of momentum, temperature and humidity.

IV. Recommendation for New Research

A detailed new proposal will be submitted, covering the following topics of research.

- A. Further statistical considerations on problems listed under IIA-C, by the use of a new version which is more adaptable to applications.
- B. Structure of spectral distributions in the inversion layers, including those in the planetary boundary layer and the troposphere.
- C. Structure of the Non-uniform fluxes.
- D. A new similarity theory predicting the mean profiles in the upper planetary boundary layer. The theory will be based upon the G-K method.
- E. A new similarity theory predicting the spectral distribution.
- F. An improved modeling of turbulence based upon the K-G method.

V. Remark

The kinetic theory based upon the modern techniques from the many-body statistical mechanics, using the various evolution operators for the description of the detailed trajectories and the memories, has recently been recognized as the most powerful method of treating the problems of turbulence in fluids and plasmas. Several centers (Universite Libre de Bruxelles, Centre d'Etudes Nuclaires Fontenay-aux-Roses, MIT, NOAA-Boulder) have devoted their attention. They have presently arrived at the same level of progress, with the same difficulties mentioned above. We strongly feel that it is important to overcome these difficulties by our scaling method described above. Our new group-kinetic theory, as described above, is found to be the most efficient in determining the spectral structure and formulating the transport theory in turbulence. More specifically, the G-K theory will provide us with a statistical basis for the numerical modeling of turbulence.

VI. List of Publications Prepared Since June 1982.

The following Technical Reports have been completed and are prepared for publication in technical journals.

- 1. Group-Kinetic Theory of Turbulent Collective Collision
- 2. Group-Kinetic Theory of Two-Dimensional Geostrophic Turbulence
- 3. A New Kinetic Description for Turbulent Collisions Including Mode-Coupling
- 4. Equivalent Methods for Quasilinear Turbulent Trajectories
- 5. Group-Kinetic Theory of Shear Turbulence

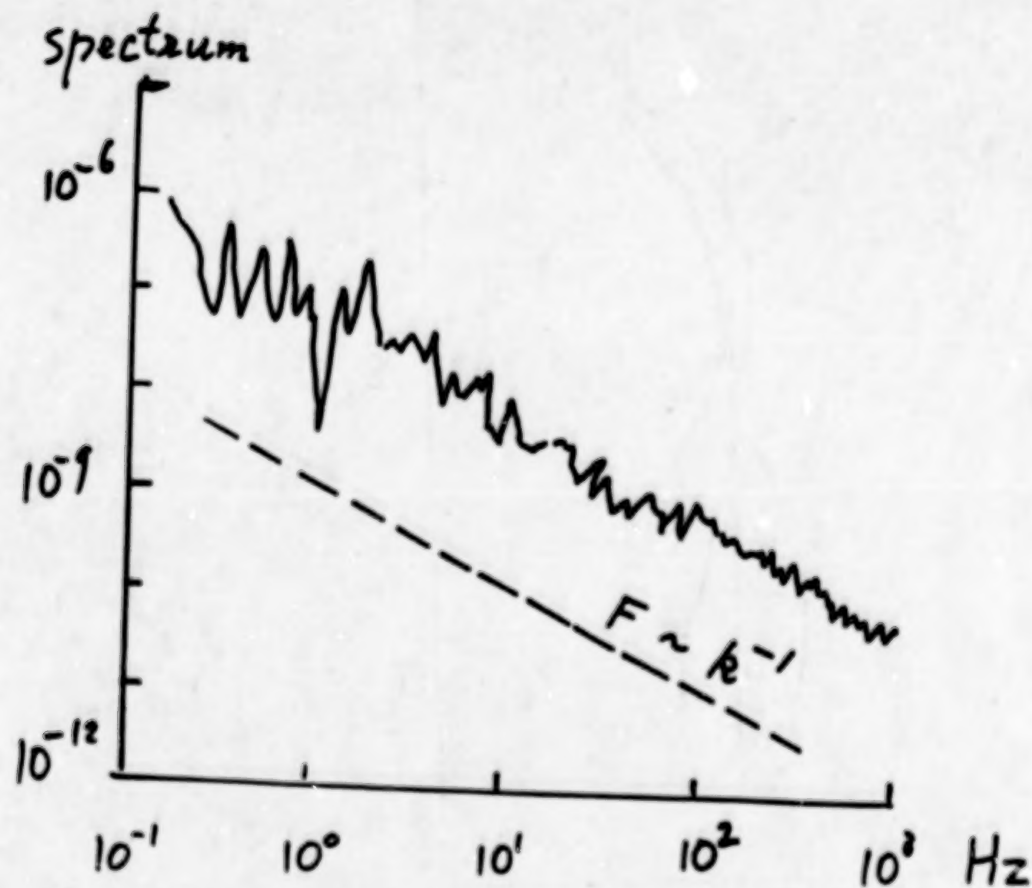


Fig. 1. Flight hotwire anemometer data in the troposphere at altitude 11 km.
The spectral law k^{-1} is predicted by Tchen's theory.

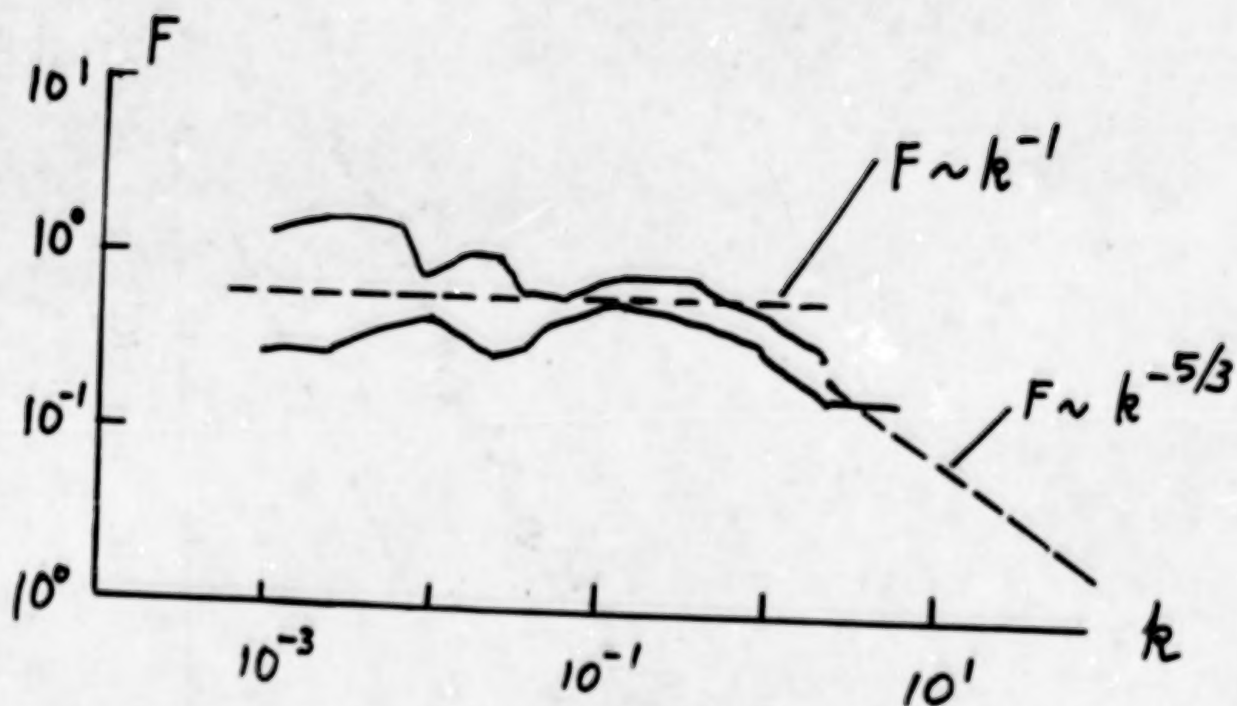


Fig.2 Kansas data in the nearly neutral surface layer at $z=5.7$ m ($z/L=-0.04$ and 0.03). The spectral law k^{-1} and the transition to $k^{-5/3}$ is predicted by Tchen's theory.

TITLE: Numerical Studies of Baroclinic Flows

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Significant Accomplishments FY-83:

Incompressible axisymmetric baroclinic flows in cylindrical and spherical configurations were studied by use of numerical models developed in FY 82. This code implementing the numerical model, can be used to solve two types of basic flow problems in a large variety of configurations. First of all, it can be used to study steady-state solutions for time dependent flows by sophisticated time-stepping procedures that allow variations in time steps depending on the physical parameters and their locations. Second, the code can be run in complex arithmetic to test the flow for stability when subjected to small non-axisymmetric disturbances. The code contains software to produce a variety of graphical outputs on both a line printer and on a Tektronix plotter.

Testing of stability analysis section of the code was started in FY 83. A systematic survey of basic axisymmetric states for specified configurations and parameters was begun. In particular, an attempt to numerically verify the experimented results of Hide and Fowles for the cylindrical annulus was started. This work will produce a flow regime diagram for the stable and unstable regions.

Also, aspect ratio tests for a spherical hemisphere were performed. A package of results was also prepared to be used in bench testing for Marshall's proposal for a high speed parallel processor.

Focus of Current Research Activities:

Efforts to produce regime diagrams for the annulus will continue. It is also expected that a regime diagram for spherical geometry will be completed.

Plans for FY-84:

Development of a new three dimensional code using the same VAX computers as used at present. Modifying the code to run on a high speed vector processor would speed up numerical processing by a large factor.

Publications:

"Numerical Studies of Baroclinic Flows in Spherical Geometry," W. W. Fowles, T. L. Miller, G. O. Roberts, and K. J. Kopecky. Presented at Conference on Atmospheric and Oceanic Waves and Stability sponsored by AMS, March 1983.

The Role of Latent Heat Release in Baroclinic Waves

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Significant Achievements to Date in FY-83:

(a) Model without β -effect--A new rotational Froude number is defined in terms of the total width of the domain and the zonally-averaged static stability. In comparison with the dry model, the inclusion of latent heat release tends to reduce the total domain size of the wave of maximum growth rate of the first mode, and to confine the second mode to the large total domain size with at least one family of the mode having larger growth rate than the corresponding growth rate in the dry case. However, the maximum growth rate in all cases is equal to that of the dry model. The similarities and differences between this model and the models of Gall(1976) and Haltiner(1971) have been investigated.

(b) Model with β -effect--The formulation has been re-examined. With the conditions that the vertical motion vanishes at the vertical interface between the pseudo-adiabatically ascending region and the dry adiabatically descending region, the earlier result is still valid, i.e. for a given mean zonal wind shear there exists only one unstable wave. When beta is set equal to zero, the formulas for the vertical motion becomes the form previously obtained.

Focus of Current Research Activities and Plans for FY-84:

Various approaches to improve the model have been contemplated. The Ekman pumping effect coupled with the effect of latent heat release is one of these problems. Another problem is the effects of latent heat release in baroclinic waves in Eady model.

List of Publications published and prepared since June 1982:

Tang, C-M., and Fichtl, G. H., 1983: The role of latent heat release in baroclinic waves--without β -effect. J. Atmos. Sci. 40, 53-72.

Tang, C-M., and Fichtl, G. H., 1983: The non-quasigeostrophic effects in baroclinic waves with latent heat release. Presented at the Fourth Conference on Atmospheric and Oceanic Waves and Stability of the American Meteorological Society, March 22-25, 1983, Boston, Mass.

References:

Gall, R., 1976: The effects of released latent heat in growing baroclinic waves. J. Atmos. Sci. 33, 1686-1701.

Haltiner, G. J., 1971: Numerical Weather Prediction. Wiley & Sons, 317pp.

TITLE: Numerical Calculation of the Regime Diagram for the
Atmospheric General Circulation Experiment

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SIGNIFICANT ACCOMPLISHMENTS FOR FY83:

During the past year our work concerning the development of the computer programs necessary for the computation of the transition curve on the regime diagram for AGCE was completed. In fact the results have been written up and will appear in the Journal of Atmospheric Science. The significant results of that research were described in the October review for FY82. Therefore they will only be briefly sketched here.

First the models were used to compute the regime diagram for the rotating annulus. This was accomplished for code written for the spherical configuration of AGCE by setting the radius of the sphere to a very large number and considering a small area near the pole.

The series of numerical calculations consisted of first computing the axisymmetric solution that would develop in the annulus in the absence of waves for a given thermal forcing and rotation rate. This flow was then tested for stability using a linear primitive equation model. If the flow was stable then the point on the regime diagram corresponding to the particular rotation rate and thermal forcing of the experiment was considered to be on the axisymmetric side of the regime diagram. If it was unstable then the point was assumed to be in the wave regime. In this way the transition curve (the line separating these two regimes) was constructed for the annulus. The results were that over a wide range of rotation rate and thermal forcing, the transition curve can be accurately predicted using these models. This result shows that the transition curve is given by the linear instability of the flow that would develop in the absence of eddies. That is, the linear theory explains the curve.

We also used the model to compute some axisymmetric flows for one possible configuration of AGCE. This work suggested that some design changes in the AGCE experiment may be desirable to provide more earth like flows within the apparatus. For this reason a detailed regime diagram was not constructed at this time. This work will be continued by Dr. Fowles and others at the Marshall Space Flight Center.

CURRENT FOCUS OF RESEARCH WORK:

Since we have essentially completed the work to develop numerical models for computing the transition curve for the annulus, we began during the winter to look at an important dynamical question suggested by the annulus experiments but which also is important in several other problems including AGCE, the general circulation of the atmosphere and tornadoes. This work will be the Ph.D. thesis of Jerry Steffens.

The purpose of this current research is to investigate the effect of geometrical constraints on the size of eddies developing from a basic state. In other words if we hypothesize that eddies like to be more or less round and that their dimension across the unstable region is given by the width of this region, then any geometrical constraint on the width of the unstable zone will ultimately limit the size of the eddies to wavelengths about equal to that width. For example in the annulus, this width and hence the wavelength would be determined by the width of the annulus. If one examines a regime diagram for the annulus, a preference for waves of a length about equal to that width is clearly displayed. In AGCE, the general circulation and tornadoes, this geometrical constraint will be the width of the shear zone or the baroclinic zone. This geometrical constraint has been shown to influence the most unstable wavelength in a number of barotropic and baroclinic flows. However, it must also play an important and perhaps different role when the waves are of large amplitude and highly non-linear. Our plan is to examine both barotropic and baroclinic flows, using linear and nonlinear models. We believe that the results will help explain the scale-selection mechanism of baroclinic eddies, in the atmosphere experimental models such as AGCE and the multiple-vortex phenomenon in tornadoes.

RECENT PUBLICATIONS:

1. Thermally Driven Flow in a Rotating Spherical Shell: Axisymmetric States. T. L. Miller and R. L. Gall. J. Atmos. Sci., 40, xxx-xxx.

2. A Linear Analysis of the Transition Curve for the Baroclinic Annulus. T. Miller and R. Gall. Submitted to J. Atmos. Sci.

TITLE: Numerical Studies of Fundamental Dynamics of Rotating Fluids
Using a Modified General Circulation Model

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SIGNIFICANT ACCOMPLISHMENTS FY-83:

Our research objective is to carry out and interpret rotating-annulus-type experiments using a nonlinear numerical model in spherical geometry. The model that we have been using is the operational general circulation model at the National Center for Atmospheric Research, but as modified by us. These modifications consist of dropping such components of the model as the hydrological cycle and replacing the lower boundary with a uniform surface having a prescribed latitudinally varying temperature. We have described in earlier progress reports some of the results obtained when this model is run with a spectral truncation at wavenumber seven. These may be very briefly summarized here by noting the differences between the regime diagram generated from this spherical geometry model and the regime diagram generated from laboratory rotating annulus experiments. In the spherical-geometry, model-generated regime diagram there is 1) no upper symmetric regime and 2) wave activity at low rotation rates is maintained by barotropic rather than baroclinic processes.

These and other results we described in a manuscript submitted for publication late in FY 82. Reviewers of this manuscript questioned the use of wavenumber seven truncation and suggested that we look at the extent to which some of our results might depend on the resolution of the model. Thus, in FY 83 we repeated many of our numerical experiments with the model truncation set at wavenumber 15, which gives twice the horizontal resolution. These new calculations demonstrate that the results reported in the original manuscript were not artifacts of wavenumber seven truncation. We did, however, find some differences in detail. For example, in the case with wavenumber 15 truncation, the boundary separating the wave regime from the axially symmetric regime was shifted in position somewhat at low rotation rates. The manuscript has been revised to include description of the minor differences between experiments with these two models differing only in the truncation, and this has been submitted again for publication.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

We are presently involved in designing numerical experiments to elucidate how the axially-symmetric circulation at geophysical rotation rates depends on the equator-to-pole temperature distribution and on the presence or absence of waves in the model. We have noted in previous model runs that the Ferrel cell is absent and that the Hadley cell is sometimes split into two cells. We would like to find out what circumstances are producing this behavior. There are several model studies in the literature of the axially-symmetric component of the tropical atmospheric circulation [that is, the Hadley cell.] We are presently trying to reproduce these results with our model by using the heating function employed in these studies and by dropping all waves from the solution. We plan to repeat these model runs with the waves retained (using wavenumber -15 truncation) to see how this modifies the Hadley cell. We will also search for modifications in the heating function that will permit the waves to force a Ferrel cell.

PLANS FOR FY-84:

The computing facility at the National Center for Atmospheric Research is currently being restructured, resulting in a delay in our computing that will continue on into the summer. It now appears that we will continue on into FY 84 with the task described above as current research activity. We also propose two other tasks for FY 84. The first is that of running the model with a more physically realistic thermal drive that allows the static stability to increase with increasing latitudinal temperature gradient. The purpose is to test the hypothesis based on our present model results that the upper symmetric regime does not exist in spherical geometry. The second task is to establish the climate of the model we have been using to generate regime diagrams. In particular, we wish to find out if the climate of this relatively simple non-linear model is transitive or intransitive. In this task we will follow the procedure outlined in the second-year part of our original proposal.

PUBLICATIONS SINCE JUNE 1982:

Rotating-Fluid Experiments With an Atmospheric General Circulation Model
(submitted to J. Geophys. Res.)

Title: Observational and Theoretical Studies of the Evolving Structure of Baroclinic Waves

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Significant Accomplishments FY-83:

- 1) Analytical solution for low and middle level cloud structure in a growing baroclinic wave: Preliminary calculations have now been made revealing the dynamical processes involved in the evolution of the "comma-shaped" cloud patterns often observed on satellite imagery (Saltzman and Tang)
- 2) Observational study of the energetics of blocking weather patterns: A study was completed showing that in blocking situations there is a tendency for both energy and enstrophy to flow toward the lowest wave-numbers in the planetary flow. This is in marked contrast to the more typical, non-blocking, situation in which enstrophy always cascades toward higher wave-numbers (Hansen)
- 3) Theoretical study of atmospheric blocking patterns: The influence of stochastic weather noise on a bistable mountain-induced barotropic flow has been completed. This study reveals the great sensitivity of the "exit-time" between equilibrium states (one of which represents blocking) to the parameters of the problem. It is also shown that even if bistable equilibria exist they are unlikely to be observed in meteorological data because of the noise level imposed by baroclinic perturbations. (Hansen)

- 4) Data acquisition: We have now secured an eight year record (1974-1982) of twice-daily global, digitized, observations of the infrared radiation leaving the earth as measured by the NOAA/NESS operational satellite. We plan to analyze this data for cloud-baroclinic wave signatures and for blocking signatures (Saltzman, Hansen, Nagle)

Focus of Current Research, and Plans for FY-84

We are continuing our development of analytical models of the cloud structure of baroclinic waves (Item 1, above), and in addition, plan to generalize the study to include the behavior of arbitrary passive tracers in baroclinic systems. A major effort will also be made to exploit the satellite observational data base we have acquired (Item 4). A new study will be undertaken to explore the nonlinear behavior of baroclinic waves far from their point of unstable equilibrium, using the theory of stochastic-dynamical systems analysis.

Publications Prepared Since June 1982:

- 1) Hansen, A.R. and A. Sutera, 1983: A comparison of the spectral energy and enstrophy budgets of blocking versus nonblocking periods. Tellus (in press)
- 2) Benzi, R., A.R. Hansen, and A. Sutera, 1983: On stochastic perturbation of simple blocking models. Quart. J. Roy. Met. Soc., (submitted).

THEORETICAL AND EXPERIMENTAL STUDIES IN SUPPORT OF THE
GEOFYSICAL FLUID FLOW EXPERIMENT

May 1983

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Meteorologists and astrophysicists interested in large scale planetary and solar circulations have come to recognize the importance of rotation and stratification in determining the character of these flows. In particular, the effect of latitude-dependent Coriolis force on nonlinear convection is thought to play a crucial role in such phenomena as differential rotation on the Sun, cloud band orientation on Jupiter, and the generation of magnetic fields in thermally driven dynamos. Most theoretical and all experimental work on these problems has in the past treated only local curvature effects--the mid-latitude or equatorial β -planes of meteorology being well-known examples. In fact, terrestrial laboratory experiments have only been able to study β -plane flows in situations where the stratification is extremely simple, usually two layers of fluid of slightly different density. The continuous low-g environment of the orbiting space shuttle offers a unique opportunity to make laboratory studies of such large-scale thermally driven flows under the constraint imposed by rotation. This is possible because polarization forces in a dielectric liquid, which are linearly dependent on the fluid temperature, give rise to an effectively radial buoyancy force when a radial electrostatic field is applied. The Geophysical Fluid Flow Cell (GFFC) is an implementation of this idea in which fluid is contained between two rotating hemispheres that are differentially heated and stressed with a large a-c voltage. Our group has developed a facility to analyze the temperature and velocity data that will come out of the GFFC experiment, and has been working on several theoretical and (terrestrial) laboratory problems which serve as models of the expected GFFC motions.

Research Accomplishments in FY83 (Oct. 1982 - Apr. 1983)

A. GFFC Data Analysis.

Data from the GFFC consists of thermal and dye-line images, and decimal and binary LED registers all recorded on 16mm film. These images will be read by a digitally addressable TV scanner. The programming of this data reduction system was completed, except for some tuning of the codes that read the dye lines. Since the dye lines (that are injected photochromically) both dissipate and deform with time, it has been difficult to generate and test accurate location routines since the available GFFC test films have velocity deformations very much larger than those expected in Spacelab (because terrestrial gravity is 5 to 10 times larger than the 'dielectric gravity'). This situation should improve with further terrestrial instrument tests described below.

B. Support of GFFC Instrument Development

The previous test films from the GFFC ground-based experiments were made using a positive video news film (Eastman 7250, ASA 400). The contrast and resolution of this emulsion are too high and low, respectively. Therefore several alternative films were tested with the hope of obtaining substantially higher resolution and lower contrast (more dynamic range). It was found that Eastman 7247 negative Kodachrome emulsion (ASA 100) was far superior to other high or medium speed emulsions and the use of this film is now being implemented in the GFFC.

C. Theoretical and Numerical Studies

Several numerical studies of various aspects of convection were completed by Toomre and collaborators. These focused on processes in solar convection, and in transitions to chaotic flow in certain constrained thermosolutal convection situations. These provide a background for the interpretation of the GFFC experiments on large scale convective processes with a spherically symmetric and unstable thermal boundary condition.

Hurlburt completed his Ph.D. thesis on two-dimensional compressible convection. This work suggests limits for the qualitative similarity of Boussinesq convection and compressible convection as a function of the scale height to domain height ratio. Since the GFFC uses a dielectric liquid as the working fluid it is, of course, Boussinesq (incompressible).

Hart developed a theory for tilted or rotated convective fluid loops and showed that in general the bulk motions should be described by a modified form of the 3 component model of convection due to Lorenz, that possesses a very rich bifurcation structure.

D. Laboratory Studies.

A laboratory study of convective motions in a toroidal loop of fluid was initiated. This loop convection model is intended to elucidate the bifurcation sequences leading to chaotic or turbulent motions in very simple systems with strong geometrical constraints. The study will help in our interpretation of the GFFC data. It was found that for a range of heating rates the motion in the fluid torus followed the sequence proposed by Lorenz, namely a bifurcation from steady circumferential motion to chaos, directly with no periodic regimes. However a second type of non-circumferential periodic motion was also observed.

Plans for FY-84 (including May 83-Oct. 83)

A. Support of Ground Based GFFC Testing.

The overall plan is to evaluate and calibrate the GFFC instrument by conducting a series of ground-based experiments and comparing the results with theoretically and numerically derived predictions. These 'science' runs will be conducted at MSFC with the instrument in the inverted or statically stable configuration. The flows then will be steady and axisymmetric over a wide range of parameters and thus can be easily compared to relatively simple numerical predictions.

B. Numerical Simulation of GFFC Flows.

The three-dimensional spectral model of G. Glatzmaier will be converted for use in GFFC simulations. This should run faster and be more accurate at the poles than current grid-point models. Several linear eigenmode calculations will be run to define the neutral stability curve for rotating spherical flows with $1/r^5$ gravity. This will help in the

generation of the experiment selection for the spacelab 3 flight of the GFFC.

C. Spacelab 3 Mission Support.

In addition to supplying science-test and flight scenarios for the GFFC, we anticipate participation in payload specialist training, payload integration, and flight operations.

D. Theoretical and Laboratory Studies.

A number of low-order models of convective systems will be studied. The truncations will be suggested by strong geometrical constraints (as in the terrestrial laboratory work) or by rotation (as in GFFC, where strong rotation, theoretically at least, should cause a preference for almost two-dimensional convective cells). These theoretical models will be compared with laboratory studies where possible, focussing on questions of hysteresis, multiple equilibria, basins of attraction, and transistion to chaos.

Papers Submitted (wholly or partially supported by NAS-8-31958)

Hart, J., Low Prandtl number convection between differentially heated end walls. Int. J. Heat and Mass Transfer. In Press.

Hart, J., A new analysis of the closed loop thermosyphon. Submitted to Int. J. Heat and Mass Transfer.

Latour, J., J. Toomre, and J.-P. Zahn., Non-linear anelastic modal theory for solar convection. Solar Physics. In Press.

Moore, D.R., J. Toomre, E. Knobloch, and N.O. Weiss. Chaos in thermosolutal convection: Period doubling for partial differential equations. Nature. In Press.

Toomre, J., D.O. Gough, and E.A. Spiegel., Time dependent solutions of multimode convection equations. J. Fluid Mech., 125, 99-122, 1982.

TITLE: Numerical Studies of Baroclinic Instability

INVESTIGATOR: Timothy L. Miller¹
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SIGNIFICANT ACCOMPLISHMENTS:

The detailed validation of models developed at the University of Arizona with Dr. R. L. Gall was performed in FY-82 by calculating a transition curve between axisymmetric and non-axisymmetric flow in the baroclinic annulus. The paper describing this research was completed in FY-83, while Dr. Miller was an NRC Associate.

A study of fully nonlinear symmetric baroclinic instability has been almost completed. In particular, the structures and energetics of the equilibrated waves has been investigated in some detail.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The work in symmetric baroclinic instability is in the process of being documented. Adaptation of linear models to study asymmetric effects is underway.

PLANS FOR FY-84:

The effect of symmetric baroclinic waves upon the stability of the flow to asymmetric perturbations will be studied. This work has relevance for the AGCE, as well as applications to mesoscale motions in the Earth's atmosphere and to the atmosphere of Jupiter.

Highly nonlinear flows (turbulence) due to symmetric baroclinic instability will be studied if computer resources become available.

RECOMMENDATIONS FOR NEW RESEARCH:

(1) Laboratory, theoretical and numerical studies of rotating and non-rotating convection with horizontal density gradients.

(2) Laboratory, theoretical and numerical studies of baroclinic flows which are mechanically driven (i.e., differentially rotating top and bottom), as well as thermally driven.

LIST OF PUBLICATIONS AND PAPERS:

- (1) Thermally Driven Flow in a Rotating Spherical Shell: Axisymmetric States. By T. L. Miller and R. L. Gall. To appear in April 1983, J. Atmos. Sci.

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LIST OF PUBLICATIONS AND PAPERS: (continued)

- (2) A Linear Analysis of the Transition Curve for the Baroclinic Annulus.
By T. L. Miller and R. L. Gall. To appear in J. Atmos. Sci.
- (3) A Study of the Rotating Baroclinic Annulus: Axisymmetric States and Linear Waves. By T. L. Miller and R. L. Gall. Fourth Conf. on Atmos. and Oceanic Waves and Stability, AMS, Boston, 1983.
- (4) The Structure and Energetics of Symmetric Baroclinic Waves. Manuscript in preparation, to be submitted for journal publication.

TITLE: GFFC Instrument Status

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Significant Accomplishments to Date in FY83:

Most of the work on the Geophysical Fluid Flow Cell (GFFC) instrument since last fall has centered around the assembly of the inner sphere. A prototype sphere was developed in November and tested as follows: (1) the sphere was maintained at 150°C for 2 hours to simulate the conditions it would experience during the plating procedure; (2) then cycled every 30 minutes between 0°C and 100°C for 24 hours using its heaters and sensors; and (3) the equator was maintained at 0°C while the pole was cycled from 0°C to 100°C every 30 minutes for 24 hours. The sphere experienced two anomalies. A single wire short-circuit to the stainless steel occurred at 65°C and vanished at 35°C. Also, a connector lead to a sensor opened at temperatures below 35°C. Since this prototype was not destined to fly, additional tests were performed to uncover further weaknesses in the sphere. As a result, the intermittent short became a permanent feature and the pole heater opened.

A failure analysis of the inner sphere was performed at Aerojet during December, and was observed by an MSFC representative. The results showed that (1) the sensor short to the stainless steel resulted from wire insulation abrasion probably due to excessive handling; (2) the open sensor problem was actually a broken lead; and (3) the heater failure was due to high electrical heating which melted the insulation. It was concluded that poor workmanship and excessive testing (viz. the extreme temperature limits) were the major contributors to the sphere's failure.

During January a Delta Design Review was held with Aerojet. The materials and assembly procedures were reviewed and the drawings were placed under configuration control. Details of the fabrication were listed on Aerojet shop orders and critical assemblies were required to be inspected by Quality Assurance personnel and DCAS before proceeding. In addition, MSFC personnel were present during critical phases. Aerojet was directed to build two spheres. One is a 'proto-flight' while the second one is to be used on a contingency basis. A different coating technique was approved in order to reduce the heat loads for this process.

In February, the temperature sensors were installed into the inner sphere. The macor sphere and heater wires were also completed and functionally checked. The testing of the sphere was done sequentially

during its fabrication. The motivation for this multiphase testing was to detect problems at critical assembly points so as to minimize any disassembly required for analysis and repair. Before the stainless steel and macor spheres were joined together they were cycled 16 times in an environment chamber between 20°C and 75°C. Afterward, the two were epoxied together and cycled 24 times between 20°C and 65°C using the macor heaters and monitored with the sensors. Next the assembly was electron-beam welded to a lower hemisphere support and cycled again 24 times from 20°C to 65°C. Finally, the sphere was machined to specifications and the cycling was repeated. The sphere successfully completed all of these test and was sent to a subcontractor for plating and polishing.

Current Focus of Research Activities:

Reassembly of the entire instrument is expected to begin in May. This will include: filling the capacitor with new oil, optical alignments, and functional tests. In addition, the GFFC will be adjusted to properly expose a different film recently selected by the PI. The GFFC Integration Readiness Review is scheduled for May 26 which will verify instrument/Spacelab interface capability and safety. The Acceptance Tests are also planned for this time period.

Currently the GFFC is expected to be delivered to MSFC in early June. At that time the instrument will undergo checkout tests in parallel with acoustic tests. The vibration test will be performed in mid-June. Finally, the off-gassing test is planned for late June or early July. Afterward, the GFFC will be devoted to ground-based tests and crew training. Final programming for flight will be performed in August and September followed by shipment to KSC.

Title: THREE-DIMENSIONAL AGCE CODE

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Significant Accomplishments in FY-83:

We are developing an efficient computer code for modeling three-dimensional AGCE flows. This code has sufficient flexibility to simulate a wide variety of incompressible flow problems, including proposed spherical-layer AGCE configurations, related cylindrical experiments, and theoretical models of the atmosphere.

The code assumes periodicity in longitude, with period either 360° or some fraction. The fraction is normally determined by the wave number of the most unstable disturbance of a steady axisymmetric solution. This computation uses our separate codes for computing axisymmetric solutions and their stability to disturbances of different wave numbers.

The code uses a staggered computational mesh, with nonuniform meshes in the radial and latitude directions in order to resolve boundary layers without inefficiency in the interior. An accurate implicit method is used, to avoid unreasonable time-step limitations. An efficient iterative method is used to solve the three-dimensional Poisson equation for the pressure.

The code can be run in either of two modes. It can be used to calculate time-dependent flows, with specified initial conditions. Alternatively, it can be used to obtain steady three-dimensional flow solutions (provided these are stable to perturbations allowed by the assumed periodicity in longitude). In the second mode, we can use time steps which vary with position and are different for temperature and velocity, in order to speed up the convergence.

The code is being developed on VAX computers, but is designed for execution on vector hardware. This involves minimizing the use of algorithms which are not vectorizable.

Focus of Current Research Activities:

We are presently refining and testing the code algorithms. The code is not yet operational.

We are also performing extensive calculations with the axisymmetric and stability codes, in order to obtain so-called regime diagrams for a number of possible AGCE configurations. A regime diagram separates parameter ranges in which axisymmetric solutions are stable or unstable.

Plans for FY-84:

We will complete the code. We will perform validations on cylindrical geometry cases where prior computations are available.

We will implement the code on the CYBER 205 computer at GSFC. We will perform speed tests and attempt to improve the vectorization as appropriate.

Within funding and computer resource limitations, we will run appropriate three-dimensional AGCE cases.

Recommendations for New Research:

We recommend the application of the 3-D code, and of the related axisymmetric and stability codes, to GFFC parameters. These computations would take advantage of the greater speed and efficiency of the AGCE codes, as compared with older models.

List of Publications:

"Numerical Studies of Baroclinic Flows in a Spherical Geometry", W. W. Fowlis, T. L. Miller, G. O. Roberts and K. J. Kopecky, presented at the Fourth Conference on Atmospheric and Ocean Waves and Stability, Boston, March 1983 (American Meteorological Society).

TITLE: Theoretical Analyses of a Baroclinic Flows Related to the AGCE

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SIGNIFICANT ACCOMPLISHMENTS:

1. The study of the stability of a Hadley cell in the channel model developed earlier, with respect to three-dimensional perturbations has been completed. The results of this study are summarized in a paper format which has been accepted for publication in the Journal of Fluid Mechanics. Simultaneously an experimental apparatus, comprised of a cylindrical annulus with heating maintained at both the upper and lower lids was built by NASA/MSFC to investigate this mechanism of baroclinic instability.

The results on the three-dimensional instability were presented in a conference on Double Diffusion convection in March 1983 and also in the waves and stability conference of AMS in March 1983.

2. A computer code is being developed to study finite amplitude waves for an Eady model under the conditions of strong nonlinearity. The model being developed is pseudo-spectral with a Fourier expansion in the horizontal direction and Chebyshev expansion in the vertical. The technique used will allow for the potential vorticity to be included. It is anticipated that the code will be running later this year.

3. A numerical code has been developed to study the axisymmetric basic state of a rotating, heated spherical annulus. The code is a mixed spectral-finite difference Navier-Stokes solver with Fourier expansion in the latitudinal direction and finite difference in the radial direction.

CURRENT FOCUS OF RESEARCH:

The current thrust of research is to finish the development of the program for the finite amplitude analysis of the Eady problem. At the same time we plan to apply a novel new technique in finite amplitude analysis for studying the strong nonlinearity of the Eady problem. This technique requires a minimum of computational effort thus enabling us to carry out an extensive search in the parameter space on the strong nonlinear instability criteria. It is also intended to continue performing experiments at NASA/MSFC on the symmetric instability in a cylindrical annulus.

PLANS FOR FY83:

Our plans for FY83 are to continue the work discussed in the current focus of research and to try to bring as much as possible of it to a successful conclusion.

LIST OF PUBLICATIONS PREPARED SINCE JUNE 1982:

1. Symmetric Baroclinic Instability of a Hadley Cell. B. N. Antar and W. W. Fowlis, J. Atmos. Sci., 39, 1280 - 1289.
2. Frozen Time Convective Instability of a Solidifying Binary Alloy Liquid. F. G. Collins and B. N. Antar, Bull. Am. Phys. Soc., 27, 1171.
3. Symmetric Baroclinic Instability of a Hadley Cell. B. N. Antar and W. W. Fowlis. Bull. Am. Phys. Soc., 27, 1202.
4. Three-Dimensional Baroclinic Instability of a Hadley Cell for Small Richardson Number. B. N. Antar and W. W. Fowlis. To appear Journal Fluid Mechanics.

TITLE: Theoretical Flow Regime Diagrams for the Atmospheric General Circulation Experiment (AGCE)

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SIGNIFICANT ACCOMPLISHMENTS:

The major criterion for the design of the AGCE is that it be possible to realize strong baroclinic instability in the apparatus. To ensure that this criterion be met, accurate calculations to determine the transitions between the stable and unstable flow regimes must be carried out. These calculations are being performed by first determining the axisymmetric basic states with a fully nonlinear, two-dimensional, numerical model and then determining the stability of these basic states to zonal perturbations with a linear numerical model. The full procedure involves selecting a geometrical configuration and dimensions for the apparatus and a heating and cooling configuration of temperature distributions on the boundaries. The basic states and their stabilities are then determined for a given liquid and quantitative variations of the temperature differences and rotation rate. Significant accomplishments to date in FY-83 are the following:

1. The numerical basic state and linear stability codes have been thoroughly checked in cylindrical form by comparing their predictions against the previously experimentally determined regime diagram for the differentially heated and rotating cylindrical annulus flows. Since this work constitutes the first accurate theoretical determination of this regime diagram, a publication was prepared.
2. The spherical terms in the axisymmetric code are being checked by comparing theoretical predictions of homogeneous spin-up in a sphere of fluid with accurate laser-doppler measurements of the flow. To date, several sets of linear and nonlinear experiments and computations have been performed and preliminary comparisons show very good agreement.
3. Although it has been decided that the AGCE configuration will consist of a silicone fluid contained between two hemispheres with a rigid boundary

at the equatorial plane, this still leaves various possibilities, with respect to a high latitude boundary and the temperature boundary distributions, to be examined. Axisymmetric basic state flows for fifteen different geometrical configurations and temperature distributions have now been computed. Some of these flows have been shown to exhibit two-dimensional instability and unsteadiness which present problems for linear stability analysis.

4. A spherical annulus configuration which produced only steady basic state flows has been chosen for the first set of stability analyses. This configuration consists of a high latitude boundary with heating and cooling at the equatorial and high latitude boundaries, respectively. The hemispherical boundaries are thermal insulators.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The flow regime diagrams for the spherical annulus configuration is being systematically determined. Delays due to non-convergence of the stability code have occurred, but these problems are being worked out. Preliminary indications are that the spherical baroclinic flows are more stable than their cylindrical counterparts.

PLANS FOR FY-84:

Regime diagrams for several possible AGCE configurations will be prepared. Further studies of the two-dimensional instabilities and unsteadiness will be performed. It is also planned to run the AGCE codes using the dimensions, rotation rate, etc., of the Earth's atmosphere. This work should provide valuable links between the laboratory model and the real atmosphere.

RECOMMENDATIONS FOR NEW RESEARCH:

Variations of the basic AGCE model could lead to further atmospheric and oceanic modeling. A rotating outer sphere and longitudinal boundaries would model the large-scale ocean basin calculations.

PUBLICATIONS AND PRESENTATIONS SINCE JUNE 82:

1. Numerical Calculation of the Regime Diagrams for the Atmospheric General Circulation Experiment. R. Gall and T. Miller. Proceedings of the International Conference on Computational Methods and Experimental Measurements, ISCME, Washington, DC, July 1982.
2. The Numerical Design of a Spherical Baroclinic Experiment for Spacelab Flights. W. W. Fowlis and G. O. Roberts. Proceedings of the International Conference on Computational Methods and Experimental Measurements, ISCME, Washington, DC, July 1982.
3. Numerical Studies of Baroclinic Flows in Spherical Geometry. W. W. Fowlis, T. L. Miller, G. O. Roberts and K. J. Kopecky. Fourth Conference on Atmospheric and Oceanic Waves and Stability, AMS, Boston, MA, March 1983.
4. A Study of the Rotating Baroclinic Annulus: Axisymmetric States and Linear Waves. T. L. Miller and R. L. Gall. Fourth Conference on Atmospheric and Oceanic Waves and Stability, AMS, Boston, MA, March 1983.

5. Thermally Driven Flow in a Rotating Spherical Shell: Axisymmetric States. T. L. Miller and R. L. Gall. To appear in April 1983, J. Atmos. Sci.
6. A Linear Analysis of the Transition Curve for the Baroclinic Annulus. T. L. Miller and R. L. Gall. To appear in J. Atmos. Sci.

TITLE: Laboratory Back-up Studies for the AGCE

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SIGNIFICANT ACCOMPLISHMENTS:

1. Dielectric Liquid Survey

A wider range of experimental parameters could be covered with the AGCE if the dielectric body force could be increased. The only practical way to increase this force is to find a suitable dielectric liquid with a higher value of the dielectric constant than that for the silicone fluids. Unfortunately, there is a general rule that as the dielectric constant increases, the electrical resistivity decreases and low resistivity means ohmic heating. After performing systematic laboratory surveys and talking with experts on dielectric liquids, we concluded that we cannot improve on the silicone fluids. This conclusion reaffirms the need for the AGCE to be operated in an orbiting vehicle.

2. Experimental Studies With the Cylindrical Version of the AGCE

Under previous funding, an apparatus, which is a cylindrical version of the AGCE, was constructed. This apparatus has sapphire discs for endwalls so that the flow can be observed and accurate endwall temperature boundary conditions maintained. (Sapphire material is a good conductor of heat.) The original design allowed for heating and cooling only on the endwalls but the apparatus has now been modified so that it can also be set up as a cylindrical annulus with heating and cooling on the cylinder walls. This modification, when combined with the original design permits great flexibility in studying the effects of different temperature distributions on the boundaries.

The AGCE numerical design studies showed axisymmetric instabilities for some conditions and, as part of a general scientific back-up program for the AGCE, it was decided to look for symmetric baroclinic instability in the laboratory. This instability has never been observed for sure in a laboratory experiment. Experiments performed under the appropriate conditions of low Richardson number showed, in general, three-dimensional flows. In some cases, symmetric rings did appear, but they were transient; a short wavelength zonal instability quickly grew and destroyed the symmetric flow. We believe we are seeing a convective instability of the boundary layer and this conclusion is strongly supported by some numerical modeling. This boundary layer could be removed by rotating the upper boundary disc consistent with the thermal wind.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

An apparatus in which it will be possible to rotate differentially the upper boundary while at the same time maintain the appropriate boundary conditions is being designed. A numerical model of this apparatus is being used to assist in the design. We anticipate finding symmetric baroclinic instability.

PLANS FOR FY-84:

Several theoretical workers have suggested that more valuable laboratory experiments on baroclinic instability could be performed with mechanically-driven stratified flows. The differentially rotating apparatus which we are building could be used for such experiments. This apparatus will provide additional scientific back-up for the AGCE and will point to possible future space geophysical flow experiments.

TITLE: Potential Research on Coupling Between Atmospheric and Land Systems as Related to Desert Formation Processes: Impact on Climatic Changes and Global Habitability

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Significant Accomplishments to Date in FY83:

1. Preliminary literature survey, followed by a 2-day colloquium and informal workshops between MSFC atmospheric scientists and U.S.G.S. geoscientists, and subsequent exchange of ideas which had been initiated in FY-1982, continued in FY-1983.

2. On October 22, 1982, a second informal workshop was held at MSFC between members of the Atmospheric Sciences Division and the U.S.G.S. Desert and Eolian Processes Study Group.

3. As a result of these discussions and further interaction between our atmospheric scientists and the U.S.G.S. geoscientists, it was clearly indicated that:

a. The proposed research is within the scope of the Global Habitability Program, as stated in Dr. Edelson's memo of November 5, 1982, and addresses one of the crucial scientific issues identified in the Goody report, "Global Change: Impacts on Habitability."

b. Desertification is a current and critical problem.

c. Because of nonlinear and irreversible biogeophysical feedbacks and interactions between desertification-prone areas and atmospheric systems, desertification is a complex and poorly understood phenomenon.

d. Desertification is a global phenomenon and of direct concern to the United States.

(1) Based on climatic data, more than one-third of the solid earth's surface is desert or semi-desert. Based on soil and vegetation characteristics the total desert area is some 43% of the earth's land surface.

(2) Desert lands include or border about 80% of the world's population.

(3) In the North American continent 37% of the land area is now undergoing various stages of desertification, out of which 10% of the U.S. land mass is in a state of severe or very severe desertification. An additional 40% of the Continental United States land mass is presently undergoing various, less severe, but nevertheless real and detectable stages of desertification.

(4) The present rate of fertile soil loss in the U.S. may be as high as 100 tons per acre per year in half a dozen major agricultural regions, including the corn belt states of Iowa, Missouri and Illinois.

e. Desertification phenomena are well suited for observations from space.

(1) Low altitude, low inclination orbits can be optimized for desert coverage.

(2) Orbital systems can provide global coverage for several years with microscale spatial resolution and mesoscale temporal resolution.

(3) Analysis of small-scale images is a quick and relatively inexpensive method to identify potential sites of desertification for further study.

(4) Orbital platform systems can utilize an integrated package of complementary sensors for a comprehensive study of various stages of desertification processes and corresponding atmospheric-land systems interactions.

f. A spaceborne scientific payload designed for the study of desertification processes could also be used to augment and complement observations/measurements of other phenomena related to the Global Habitability Program, such as infrequent but high-intensity catastrophic events of atmospheric or geologic origin (e.g. hurricanes, volcanic eruptions, etc.).

g. Ever-expanding ground-based data acquisition systems (e.g. U.S.G.S., U. S. Army Corps of Engineers) exist for regional monitoring and relay of ground-based data. Such systems can be linked to a dedicated satellite system for interactive global monitoring and study of geometeorological events.

h. Systematic synoptic coverage of hyperarid regions of the current "sand seas" of the world such as the Sahara Desert, obtained through the use of such sensors as the Shuttle Imaging Radar "SIR-A" or "SIR-B," can give clues regarding paleo climates that once supported life and, thus, aid in climate modeling efforts.

i. Comparison with the geological record is one of the best ways we have of testing our understanding of the processes that control the chemical composition of the atmosphere.

j. Desert aerosols of geologic, biologic and/or anthropogenic origin, or other optically active atmospheric trace constituents with relatively small background concentrations and (percentagewise) very large spatial variability can have strong impacts on local climate and/or habitability over short time spans.

k. A research effort on desert formation processes has a great potential for intercenter, interagency and international cooperation.

4. On December 14, 1982, preliminary inputs on proposed research were submitted to Dr. R. Hudson, NASA Headquarters, including: (a) goals; (b) purpose; (c) objectives; (d) research areas; (e) research scope; (f) program thrust; and (g) justification for proposed research.

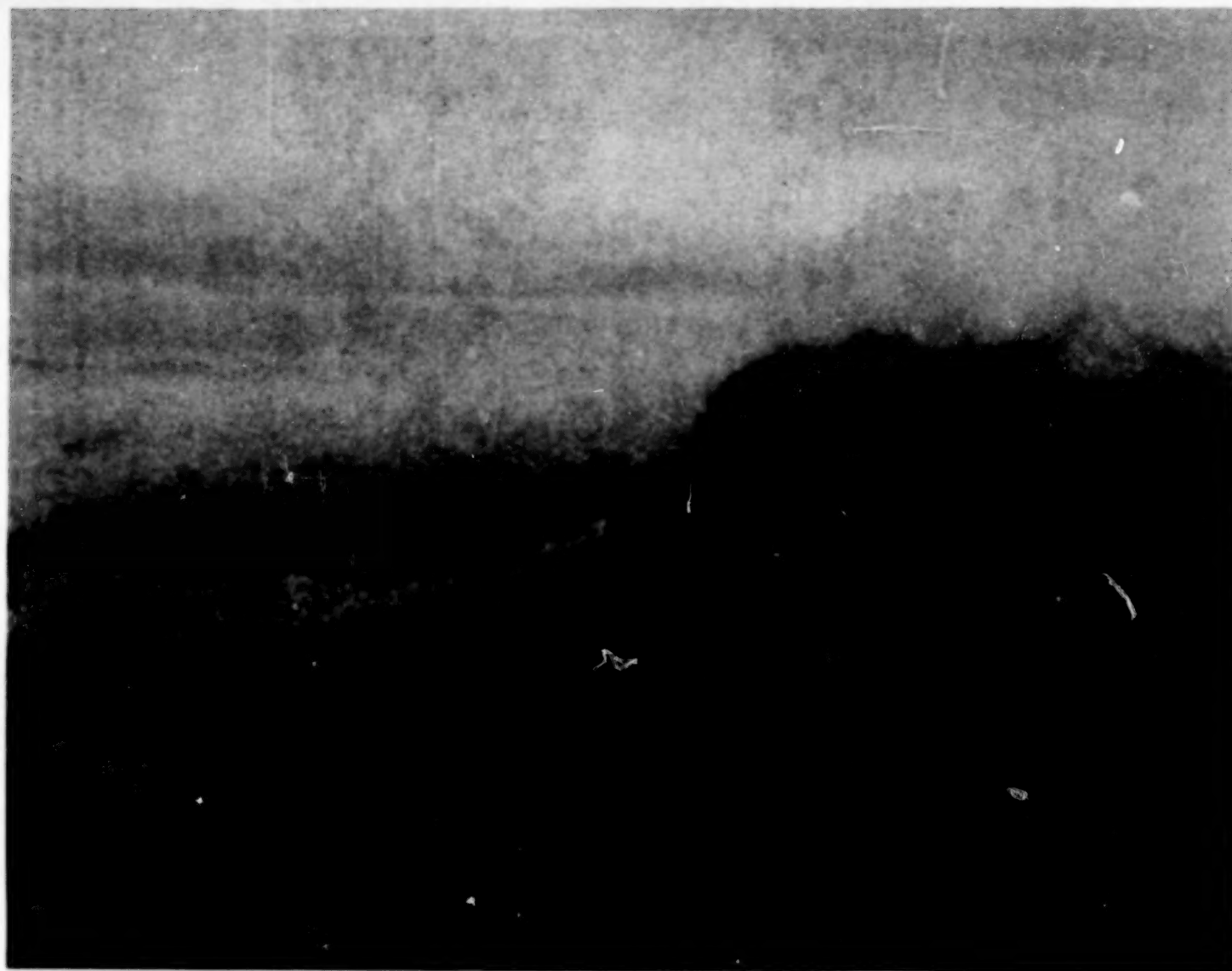
5. A preliminary research brief relating to proposed research, including: (a) scientific issues/objectives; (b) essential elements of proposed research; (c) conceptual requirements for spaceborne capabilities to conduct proposed research; (d) potential remote sensors for spaceborne observations/measurements on atmospheric-land systems interactions; and (e) recommendations for future actions, is in stage of completion.

Plans for FY84:

Initiate joint research activities with the U.S.G.S. Desert and Eolian Study Group to assess feasibility of studying desert aerosol life cycles through airborne and ground-based remote sensors, sampling and laboratory work. Long-range objectives of such an effort would be the formulation of an integrated research program on desert formation processes, involving spaceborne, airborne and ground-based investigations.

Recommendations for New Research:

(1) Explore techniques for maximizing data acquisition and analysis capabilities for studying fluxes, grain-size distributions and chemistry/chemical alterations of desert aerosols, using lidar systems, especially with multispectral switching capability, in conjunction with other active and passive remote sensors in the visible/near infrared; (2) maximize utilization of radar systems and other active/passive remote sensors to study land surface processes interacting with atmospheric systems; (3) improve remote sensor capabilities for detection of near-surface air and soil moisture conditions, especially in the presence of rough terrain, vegetation and/or snow cover.



Unusually well-developed, turbulent clouds of desert dust sweeping upward to an altitude of 1,600 m east of Bakersfield, San Joaquin Valley, California, December 20, 1977. Dust is streaming from canyons in the foothills of the Tehachapi Mountains, lower left. High peaks in the southern Tehachapi Mountains are visible above the dust cloud, center left. The dust plume at right is over Arvin, California. Photograph by Sam Chase, San Francisco, 9:00 a.m., from an altitude of 1,600 m. (Photograph through the courtesy of Howard Wilshire.)

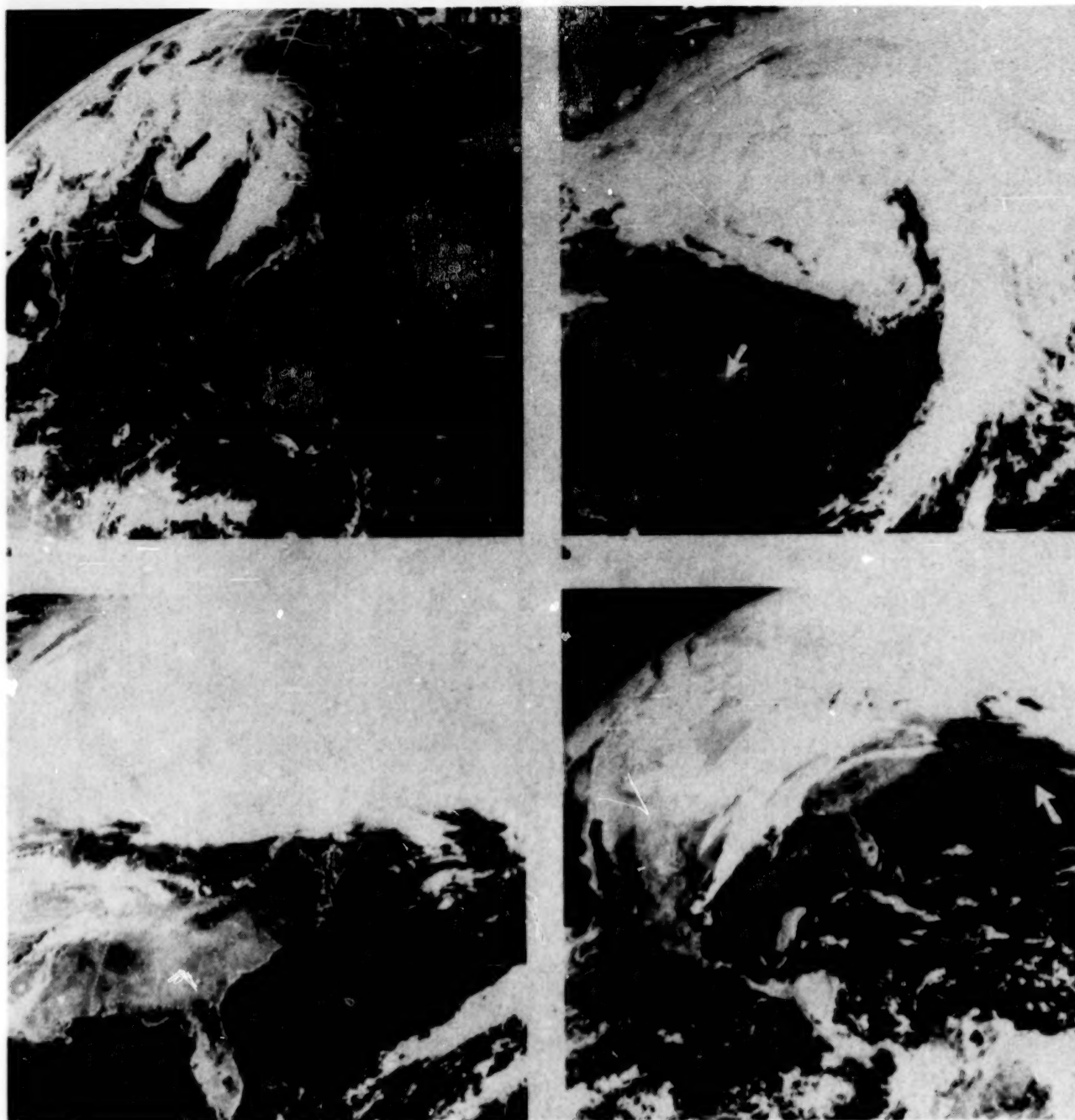


Figure 3. Sequence of GOES-1 photographs, showing regional migration of the dust pall across the central and southern United States and the Gulf of Mexico to the Atlantic Ocean on February 23-26, 1977: (a) Regional view at 3:00 P.M. MST February 23, showing areal extent of dust plume (light arrow) from source areas along New Mexico-Texas border and development of a second major dust plume from source areas in eastern Colorado (dark arrow). (b) High-resolution view at 1600 GMT February 24, showing dense dust pall reported over northern Louisiana (arrow). (c) Movement of dust across Atlantic Coastal Plain and over Atlantic Ocean at 1430 GMT February 25. (d) Persistence of dust as a discrete pall (arrow) over Atlantic Ocean at 1600 GMT February 26, three days after its origin in the High Plains.

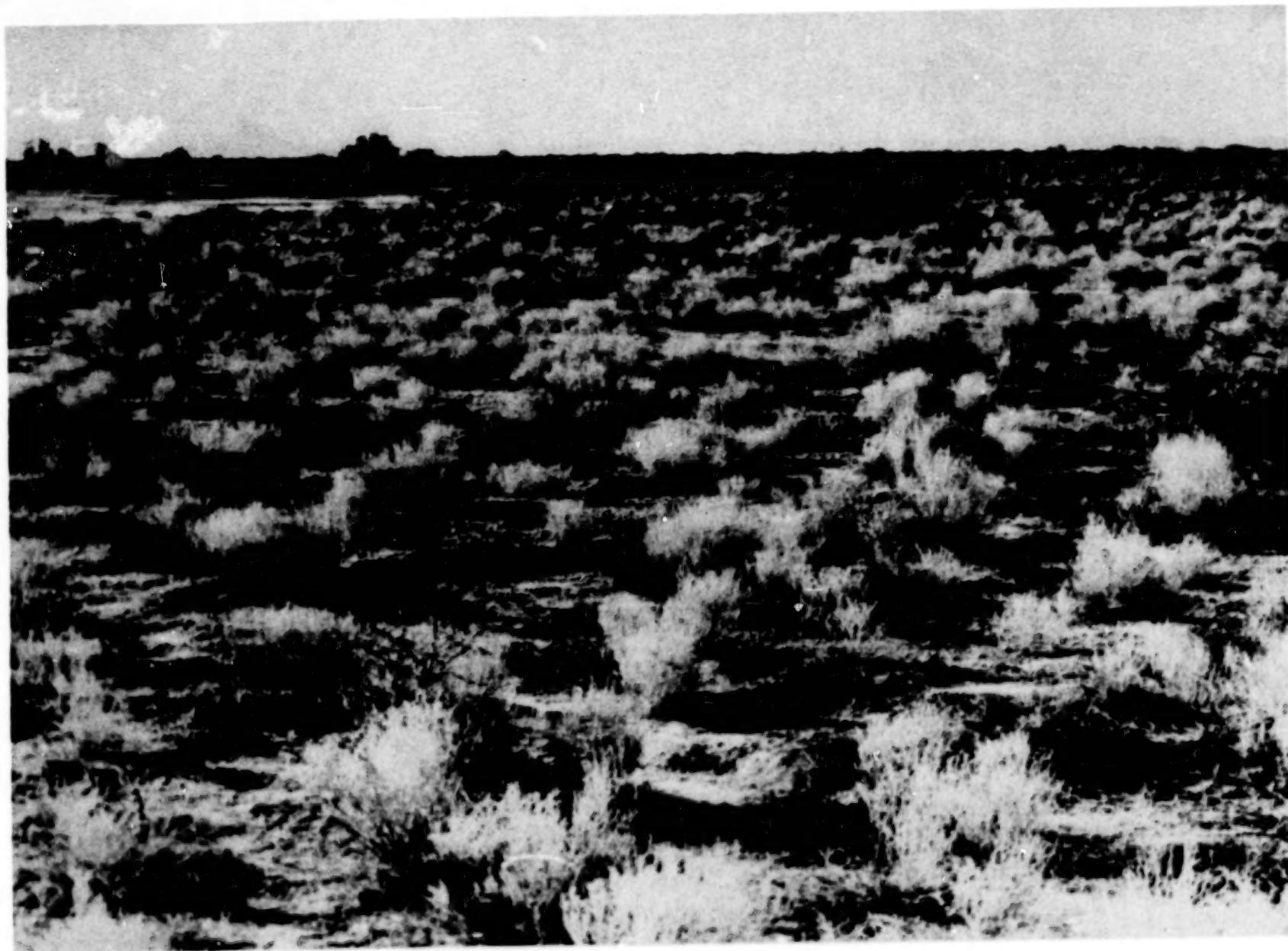


Figure 4. This field is considered to be abandoned cropland on the basis of evidence gained from aerial photos; it has nearly reverted to natural desert. (Photo by A. D. Hyers.)

DOPPLER LIDAR WIND RESEARCH

TITLE: Overview of Doppler Lidar Science Activities

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Significant Accomplishments to Date in FY83:

1. Analysis of 1981 ADLS flight data: Analysis of the data obtained in 1981 has proceeded both in-house and by investigators outside NASA. Considerable revision has been necessary in the computer processing done at MSFC to provide a useful product for the outside investigators. Revisions have been necessary both to correct errors and to provide a product that is more responsive to the users' needs. Analysis of data by outside researchers has provided inputs both for the changes in 1981 data processing and the planning for the 1984/1985 flight test program. Work done in-house to support the flight data analysis has included determination of aircraft ground tracks and drift angles to support the comparison of radar and lidar-measured winds in Oklahoma, error and bad data correction for the flight data, optimization of smoothing algorithms, and calculation of derived products such as vorticity and divergence. Important changes in plans for the hardware for the 1984/1985 flight series have been made because of the experience with the 1981 data. Development of an improved aircraft attitude sensing platform (by University of Nevada) has proceeded to the point of flight test of the hardware (June 1983). A revised control system has been designed (Lassen Research) and contract negotiations started for its fabrication. The major impetus for both of these system improvements has been the experience of in-house and outside researchers in using the 1981 flight data.

2. Planning for 1984/1985 flight program: Based on the results of the May 1982 workshop, and continued contacts with interested researchers, it has been determined that the most advantageous time periods for the next flight experiments are late summer/early fall and spring. Accordingly, a double flight program is being planned with 2 months in August/September and 2 months in February/March. Atmospheric events that are good candidates for study include midwest severe storms (spring), southwest orographic thunderstorms (fall), frontal structure over mountains and mountain waves (fall and spring), tropical cyclones (fall), regional flows (fall), two-dimensional structure in midwest cyclones (spring and fall), boundary layer structures (spring and fall), flow over complex terrain and flow about islands (spring and fall).

Current Focus of Research Work:

Activities of the outside investigators using the 1981 lidar data are being supported. Several of the analyses being performed have brought up questions about the lidar operation and data reduction. For example, differences between the wind direction as measured by radars and the lidar at Oklahoma made it necessary to look at the aircraft ground track and drift angle. The result of this analysis showed that the lidar-

measured wind direction was in agreement with other aircraft measurements, and that differences with the radars were likely due to measurement volume differences.

Plans for FY84:

The analysis of 1981 flight data will continue through most of FY84. Most of the investigators have progressed to the point that they are able to analyze the Doppler wind fields. The preliminary work (analysis of tower, radar, or aircraft data) is mainly out of the way, so that analysis of the Doppler lidar data for its science content should proceed during the second year of the research contracts. In FY84 the science requirements for the new flight series will be completed, and flight plans determined. Arrangements for science support of the fall flight experiments will be made (MSFC and PI participation in flights). The actual flights for the fall series will be performed at the end of FY84 (or the beginning of FY85 if the schedule slips).

Recommendations for New Research:

Planning for the next flight series includes research flights in FY84 and FY85. Analysis of this data will take place in FY85 and FY86. It is not possible at this time to make recommendations for research past the times indicated that would use the wind field measuring capability of the airborne Doppler lidar.

TITLE: Ground-based Doppler lidar investigations at Marshall Space Flight Center

INVESTIGATORS:

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D. E. Fitzjarrald, Atmospheric Sciences Division
J. Rothermel, Atmospheric Sciences Division
Atmospheric Sciences Division/205-453-2570
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SIGNIFICANT ACCOMPLISHMENTS FY-83:

New software has been written for the MSFC Doppler Lidar System (DLS) to provide real time plotting of vertical profiles of the horizontal wind field. This capability enables the review and optimum selection of scanning parameters during the data collection process.

Soon after returning the DLS to post-JAWS operations, it was concluded that some hardware changes were needed to insure non-interrupted data acquisition and stable lidar performance. Satisfactory operations were achieved during the last week in April 83.

Ongoing experiments and engineering checkouts include:

- * comparison of lidar wind estimates with tower anemometer measurements;
- * regular (2 x per day) β measurements with both ground based photography and satellite imagery; and
- * comparisons with local rawinsonde winds.

CURRENT FOCUS OF RESEARCH:

There are two primary scientific issues that are presently being addressed by the ground-based Doppler lidar: 1) characteristics of 10.6μ lidar backscatter from cirrus, especially subvisible cirrus; and 2) cumulus convective interactions in the subcloud layer including outflow intersection and inflow organization.

The occurrence of subvisible cirrus over north Alabama has been more frequent than expected. This has implications to the estimation of the percent of time that sufficient backscatter exists in the upper troposphere. Current estimations are based upon Air Force nephel analyses which use satellite imagery. Although the data collected at MSFC cannot be considered applicable to other regions of the globe, the results of this local study can be used to argue that the performance of a spaceborne lidar may be better than currently thought.

PLANS FOR FY-84:

The objectives for 1984 remain the same as for 1983. The ground-based operations will be interrupted in May of 84 for reconfiguration of the DLS for the Fall flight series.

PRESENTED PAPERS:

Emmitt, G. D. 1983: Ground-based CO₂ Doppler Lidar Wind Measurements in the Vicinity of Cumulus Convection. Accepted for presentation at the AMS/AIAA/NWA 9th Conference on Aerospace and Aeronautical Meteorology, June 6-9, 1983.

Title: Determination of Atmospheric Backscatter at 10.6 μm

Investigator: W. D. Jones

EB23

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Significant Accomplishment to date in FY83:

Post-Flight calibration of the instrument was undertaken. The result of lidar and signal processor calibration allowed reduction of data collected during the 80-hour 1982 flight tests. Backscatter profiles for 5 geographic locations (near Edward AFB, CA, San Joaquin Valley, CA, Owens Valley, CA, near Point Reyes, CA, and San Juan, Puerto Rico) have been plotted. The Dicke switched mode of operation proved useful in cancelling variations due to power fluctuations. Single particle and volume mode results appear to be consistent with each other.

Current Focus of Research Work

At present we are continuing to analyze data collected during the 1982 flights. A task to determine the bounds of errors in the measurement of backscatter has been written; this should be complete by the end of FY83.

We are also beginning to analyze data collected with MSFC's pulsed Doppler lidar in a ground-based configuration to determine backscatter profiles.

Plans for FY84

Our plans for FY84 are to continue data analysis on the 1982 data set, and to continue collection and analysis of ground-based pulsed lidar data. We intend to participate in the 1984/1985 Severe Storms flight experiment, mainly in a "piggy-back" mode, but with some dedicated flight hours (subject to funding approval).

We contemplate doing laboratory and ground-based measurements of atmospheric backscatter using a 9.11 μm CO_2 isotope CW laser purchased in FY82.

Recommendations for New Research

We should study work being done to predict backscatter at 10.6 μm using backscatter and extinction measurements at other wavelengths.

List of Publications

"Determination of Atmospheric Backscatter at 10.6 Microns, W. D. Jones, L. Z. Kennedy, R. W. Lee; SPIE Conference 415, Coherent Infrared Radar Systems and applications II, Arlington, VA, April 7-8, 1983.

Title: CO₂ Pulsed Doppler Lidar System - Hardware Status

Investigators:

S. C. Johnson, R. W. Rood, E. A. Weaver, V. B. Huegele, J. J. Wright and J. W. Bilbro, Optical Systems Branch, EB23 NASA/Marshall Space Flight Center, AL 35812 (205) 453-3941, 453-1597, 453-1596, FTS 872-3941, 872-1597 and 872-1596.

Significant Accomplishments

The CO₂ Pulsed Doppler Lidar System was returned from the Denver Test Program (JAWS) in August 1982. The van housing this system was in need of repair and painting. This was completed prior to the set-up of the system at the MSFC test site in October 1982. The primary effort during the time from October 1982 to April 1983 has been to make repairs and incorporate modifications to the system that provides for improved operations and data handling. A DMA 16 bit parallel interface to the Data Recording and Display System (DRDS) was designed and installed. This made possible the simultaneous recording of the signal processor data, the overhead scanner position and the data collection time. Appropriate changes were made in the executive routines and processing algorithms of the DRDS. Circuits necessary to reduce the lidar system's minimum range from 4 km were designed, assembled and tested, but further work is required to complete this modification. The remaining problems for the minimum range modification have been defined and are well understood. The Indium Antimonide Isolator was installed in the master oscillator beam path to reduce unwanted backscatter radiation. This change has resulted in improved output power stability and a frequency stability of ± 50 KHz or ± 0.25 ms⁻¹ which is the frequency stability limit of the laser.

A contract with Desert Research Institute (Dr. J. Telford) has been active since July 1982 for the development of an Inertial Navigation System (INS) based on the Litton LN 15S platform. Hardware buildup and algorithm development have proceeded satisfactorily. It is planned to have a "piggyback" checkout flight of this INS in the early summer of 1983. When completed, the INS will provide updated aircraft position information every 200 ms during the CO₂ Pulsed Doppler Lidar System Flight Test.

Progress has been slowly made toward obtaining a contract with Lassen Research (R. Lee) for the Operations Control System. This system will provide the timing, control, signal processing and data handling function as well as provide a major update for the entire lidar system. A special effort is underway to have this effort contracted by June 1, 1983.

Plans for FY-84

Ground based data collection tests at MSFC and minor system modifications are planned thru February 1984. At that time the lidar system integration tests will be started. These will include the laser system, the signal processor, the Operations Control System, the wedge scanner, the INS, the DRDS and the aircraft interface. These tests will continue until June 1, 1984 when the system will be dismantled for shipping and preparation for the flight tests in August and September 1984. A second flight test is planned for February and March 1985.

List of Publications

"Engineering Documentation for the 1981 Severe Storms Doppler Lidar Flight Program" by James W. Bilbro, July 1982.

ATMOSPHERIC EFFECTS ON COHERENT LASER SYSTEMS

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Significant Accomplishments FY-83

The standard practice in aerosol science has been to develop size distribution models of atmospheric aerosols. The size distribution models along with refractive index are used to calculate the backscatter coefficient of aerosols for the calculation of signal-to-noise ratio of atmospheric lidar systems. However, size distribution is not the best indicator of backscattering ability of aerosols as the backscatter crosssection is a multiple-valued function of aerosol size. We developed a method for obtaining backscatter crosssection from any size distribution to see the correlation between these models. The backscatter crosssection model is analytically expressible as an exponential function with two parameters. Recent experimental results from single particle measurements display similar trends for the BCS model.

Current Focus of Research Work

Carry on numerical experiments using several size distribution models and refractive indices and obtain the corresponding BCS models. Look for other simple analytical expressions for BCS models.

Plans for FY-84

Study the effects of turbulence and finite beam effects on signal-to-noise ratio of heterodyne laser systems for truncated gaussian beams.

Publications FY-83

Murty, R.: The Modeling of Atmospheric Aerosol Backscatter Crosssection at CO_2 Wavelengths, in Technical Digest of Optical Techniques for Remote Probing of the Atmosphere, January 10-12, 1983.

Research Summary Report

Evaluation of Airborne Doppler Lidar Wind Measurements (NAS 8-34730)

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FY-83 Accomplishments:

The major objective of this work is to verify the performance of a doppler lidar wind measurement system flown aboard the NASA CV-990 aircraft. This evaluation was to be accomplished in three ways: Comparison of the lidar measured wind fields with in situ measurements on a 500 meter tower, testing the sensitivity of the technique to various sources of error and computation of derivative properties of observed wind fields as a test of physical realism. In addition, confidence limits and systematic corrections based on actual line of sight doppler velocities were to be defined.

The in situ measurements from the tower have been fully analyzed in terms of the means, higher order moments and spectral distribution of the variance. These are now in a form readily useful for detailed comparison with the lidar determined wind fields.

Various analyses of the lidar data from flights 4 and 19 have been attempted. However, due to programming and data transfer problems at MSFC, full evaluation of the lidar data has not been accomplished. In addition to developing the software to handle the lidar data tapes, we have developed what appears to be an optimal scheme for identifying valid line of sight winds from noisy, invalid returns. The method computes the variance as a function of range and tests the value of the signal-versus-noise parameter 's' as a function of range. The line of sight wind data is assumed valid out to the first range bin for which s is greater than 1 and the lidar wind is greater than twice the standard deviation for the range bins up to, but not including, that bin. In other words, if $s < 1$ data is assumed good. If $s \geq 1$, the data is still taken as good unless the line of sight speed differs by more than twice the average differences from the mean out to that range.

Tests of the method's sensitivity to two kinds of errors have been performed using a computer simulation of the lidar measurements. The two types of errors examined are those due to spurious, random doppler errors and errors due to the time delay between forward and backward sampling of the same volume in space. These latter simulations impose a harmonic disturbance of selectable wavelength on the wind field which advects through the sample volume at the mean wind speed. The results of these tests indicate that the nonsimultaneity error is much larger than other sources of error, with the errors exceeding the amplitude of the imposed disturbance. The errors are largest for disturbances in the size range 1.5 to 2.5 times the sample volume longest dimension and increase as the ratio of wind speed to air speed increases.

Current Research:

We are presently refining our error analysis - especially the nonsimultaneity error. The focus is on using the moments of the line of sight winds and their wave number spectra to define the probable magnitude of the nonsimultaneity error. We will then seek to develop and evaluate a correction to the data using the mean wind field to advect disturbances so that the beam intersections and wind field recovery will be done not using a sample volume fixed in space but a sample volume moving with the fluid.

Plans for FY-84:

We expect to complete the current research on definition of and correction for systematic errors. The techniques developed from the model studies will be tested using the flight 4 and tower data. Once the techniques have been verified, they will be applied to flights 19 and 21 to develop maps of the flow regimes near the mountains surrounding the Central Valley of California.

Publications:

A manuscript describing the simulation error studies is nearly completed and will be submitted for publication by July 1, 1983.

pjl:6
5/4/83

TITLE: ANALYSIS OF MSFC DOPPLER LIDAR DATA

RESEARCH INVESTIGATOR INVOLVED: Jeffry Rothermel
USRA Visiting Scientist
ED42, NASA/MSFC
Huntsville, Alabama 35812

SIGNIFICANT ACCOMPLISHMENTS FY83:

The participation of the MSFC ground-based lidar during the Joint Airport Weather Studies (JAWS) Project in summer 1982 yielded data on approximately 13 days, constituting over 30 hours of observations. Data were gathered on thunderstorm outflows, the nocturnal boundary layer and convective growth preceding thunderstorm development. Since joining the MSFC in January 1983, I used standard objective analysis techniques developed for Doppler radar (already implemented at NCAR/ATD/FOF) to generate the first dual-Doppler analysis of wind fields by combining MSFC and NOAA/WPL lidar data collected in JAWS. Preliminary results, which show 3-D wind fields within a thunderstorm outflow, are in excellent agreement with surface wind data gathered by the NCAR Portable Automated Mesonet (PAM).

CURRENT FOCUS OF RESEARCH:

Analysis of the JAWS lidar data continues. The data are expected to yield several case histories of thunderstorm outflows, as well as yield information on convective organization prior to severe storm development. The latter is only poorly understood at present. The Doppler lidar may possess the capability to resolve mesoscale mass convergence fields that precede the development of deep convective systems.

PLANS FOR FY84:

There are 3 major objectives for FY84:

- 1) Complete the analysis of data collected by the MSFC and NOAA/WPL lidars during coordinated scans. Analyze remaining data for boundary layer phenomena, including computation of kinematic fields.
- 2) Participate in collection and analysis of data from the MSFC ground-based Doppler lidar system program. Continue to assay the capabilities and performance of the lidar as a viable mesoscale research tool.
- 3) Develop an objective analysis scheme, based on existing or new techniques, for generating 3-D kinematic fields using a single Doppler lidar.

Title: Atmospheric Backscatter At CO₂ Wavelengths For Global Winds

Investigators:

W. D. Jones, E. A. Weaver, J. W. Bilbro, J. J. Wright, Optical Systems Branch, NASA/Marshall Space Flight Center, Alabama 35812 (205) 453-3941, 453-1597, FTS 872-3941 and 872-1597.

Accomplishments

1. An Isotope CO₂ laser at 9.11 micrometers wavelengths has been purchased and is being tested in the laboratory.
2. The second multi-agency backscatter workshop was conducted on April 12 and 13, 1983 at MSFC. From 75 letters of invitation announcing the workshop about 50 people attended the sessions, of which, 36 people were from outside Marshall. Representatives were from other NASA Centers, NOAA, private industry, universities and NASA Headquarters.

Much interest was shown in the kinds of lidar backscatter studies and measurements being made by the participants. All the material presented and discussions were informative and much knowledge was shared among the participants.

A coordination committee was established from NASA and NOAA for CO₂ lidar calibration. The committee was requested to standardize calibration methods and to establish standard formats for reporting data. Greater effort among the participants is planned for the coordination of test programs. Another workshop is suggested for 1984.

Future Plans

The 9.11 micrometer wavelength CO₂ isotope laser will be used in laboratory tests and ground-based beta tests during the coming year.

TITLE: Morphology and development of organized convection in the boundary layer

INVESTIGATOR: R. W. Lee
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SIGNIFICANT ACCOMPLISHMENTS, FY-83

Substantial progress has been made in analyzing and removing several types of contamination present in the FY-81 measurements by the airborne Doppler lidar wind probe. Data correction has been achieved through improved understanding of the aircraft dynamics and the limitations of the aircraft INS system.

Recognition of pre-storm convective phenomena in the horizontal flow field requires high accuracy in the flow measurements, since the signatures of convective phenomena in the horizontal are weak. For this reason additional processing of the severe-storms wind fields beyond that required for other purposes was required.

The present accuracy obtained in flow-field reconstruction is on the order of 1 m/s or better, depending upon the level of turbulence encountered by the aircraft. Certain data sets are contaminated to a much greater degree, for reasons not yet understood.

While the intent of this study was to examine the statistical distribution of convective structures, the limited extent of the data set has required case-study methodology instead.

FOCUS OF CURRENT RESEARCH

Data from CCOPE is being examined in detail. For certain data sets dual- and triple-Doppler microwave radar data is available from chaff releases. The latter is being processed by Ramesh Srivastava. It is hoped that optical and microwave data set overlap will permit a good comparison of the two techniques.

PLANS FOR FY-84

With the accuracy of the wind fields established through internal consistency, ground returns, and comparison with microwave radars, it will be possible to examine the flow fields for the presence of convective structures.

RECOMMENDATIONS FOR FUTURE RESEARCH

Experience with boundary-layer measurements made in a single plane has suggested that oblique soundings through the boundary layer would be useful on future flights. While the horizontal extent of information at any given altitude would be reduced, information would be obtained on the scale sizes of convection throughout the entire boundary layer. This information cannot be obtained by microwave radars, due to beamwidth and clutter problems, or from acoustic sounders or FM/CW radars, which are primarily used as vertical probes.

PUBLICATIONS

Performance of the NASA/Marshall airborne Doppler lidar system, Topical meeting on optical techniques for remote probing of the atmosphere, Optical Society of America, January 1983

Boundary-layer observations with an airborne Doppler lidar, 21st conference on radar meteorology, American Meteorological Society, September 1983

ANALYSIS OF THE NASA/MSFC AIRBORNE DOPPLER LIDAR RESULTS FROM SAN GORGONIO PASS

RESEARCH INVESTIGATORS INVOLVED

Dr. William C. Cliff, Dr. David S. Renee, Raymond J. Skarda and William E. Sandusky

SIGNIFICANT ACCOMPLISHMENTS FY-83

Battelle has developed a routine to directly plot the Doppler Lidar wind vectors directly onto USGS topographic maps. From these plots, the effects that local topography has on the flow field is easily visible. Figure 1 shows the horizontal flow field from south of Palm Springs to just north of Gorgonio Pass at 500 meters (1600 ft) above grade.

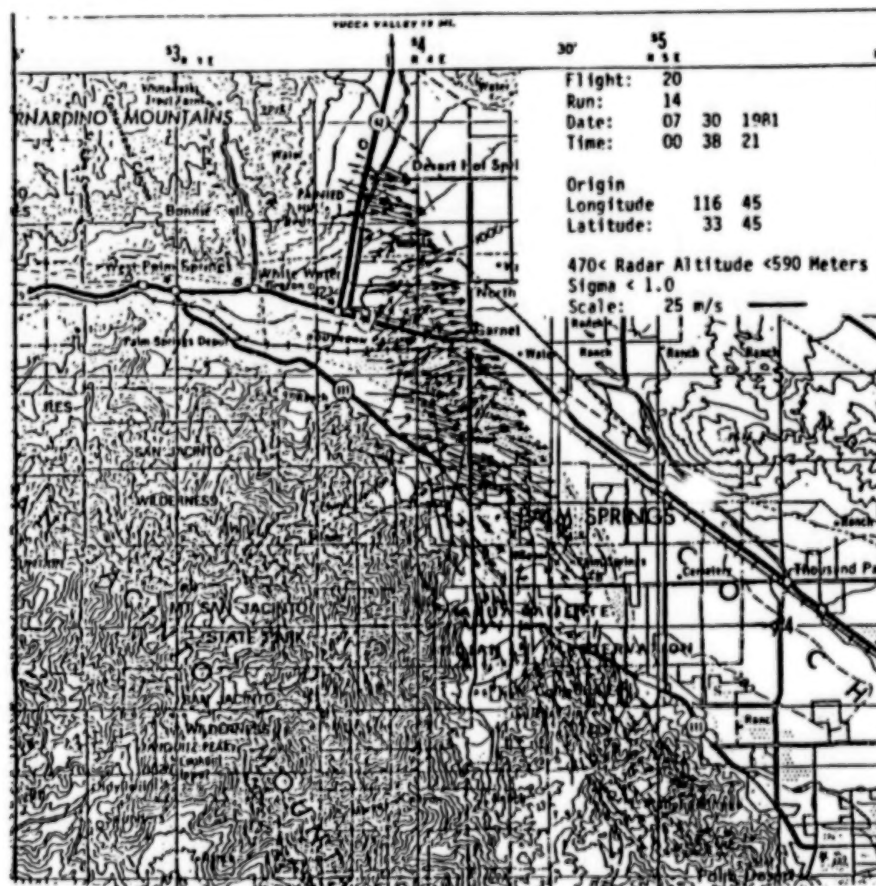


FIGURE: Horizontal Wind Vectors at San Gorgonio Pass and Palm Springs, California, (Elevation Above Grade 600 Meters, 1500 ft.)

The results of a fixed downward slant beam run is being investigated. With the knowledge of the flow direction from the horizontal beams, a vertical profile of wind velocity will be developed. The results, mean velocity and width, obtained very near the ground from the downward looking beam will be compared to data obtained from conventional sources on the ground. Statistical quantities to be compared will include mean and turbulence levels and distribution of these functions. The ground truth data is averaged for 20-30 seconds which corresponds to 200-300 meters of advected wind and for 10 minutes that corresponds to the average over approximately 20 Doppler Lidar range bins in the mean wind direction. Currently analysis indicates that the San Geronio Doppler Lidar data is good to about 20 range gates.

The following tables are a summary of some of the ground truth obtained at San Geronio Pass.

TABLE 1. Ground Truth Data for 10-Minute Averages

<u>Height above grade</u>	$\frac{\sigma_u}{\bar{U}}$	$\sigma(\frac{\sigma_u}{\bar{U}})$	\bar{U} (m/s)	$\sigma(\bar{U})$ (m/s)	σ_u (m/s)
9.1 m (30 ft)	0.166	0.0167	10.98	0.883	1.82
30.5 m (100 ft)	0.132	0.0147	12.19	0.978	1.61
45.7 m (150 ft)	0.119	0.0165	13.12	1.082	1.56

TABLE 2. Ground Truth Data for 20-Second Averages

<u>Height above grade</u>	$\frac{\sigma_u}{\bar{U}}$	$\sigma \frac{\sigma_u}{\bar{U}}$	\bar{U} (m/s)	$\sigma(\bar{U})$ (m/s)	σ_u (m/s)
9.1 m (30 ft)	0.115	0.0345	11.01	1.595	1.27
30.5 m (100 ft)	0.0778	0.0297	12.23	1.594	.95
45.7 m (150 ft)	0.0698	0.0286	13.16	1.645	.92

The above tables indicate that the near surface winds were neutral and that turbulent length scales were increasing with altitude. The distributions of the parameters listed in Tables 1 and 2 will be used in evaluating the Doppler Lidar data.

CURRENT FOCUS OF RESEARCH WORK AND PLANS FOR FY-83 AND FY-84

The principal focus of this program is to analyze the NASA Doppler Lidar Data from San Geronio Pass to determine the vertical and horizontal extent of the accelerated flow issuing from the Pass. It is the intent of the program to compare where possible the Doppler Lidar results with ground truth data. The program intends to examine the Doppler Lidar spread to determine if this parameter provides an acceptable measure of the turbulence in the focal volume. Other focuses of the research are to examine in detail the downward looking beam to determine this technique's usefulness in determining the vertical profile of the horizontal velocity.

Recommendations for New Research

Use the NASA Doppler Lidar System to investigate Strouhal/Reynolds Number relations at Reynolds Numbers of 10^8 to 10^{11} . The Strouhal/Reynolds Number tests could be performed behind a large rod shaped structure such as Table Mountain or behind an isolated island capped by an inversion layer. The system could be used in conjunction with ground based temporal sensors to investigate Taylor hypothesis (for this test the system could be mounted in an existing tall meteorological tower and pointed into the prevailing wind). The characterization of near surface flow patterns in regions of potential hazardous aerosol releases would also be useful in the development and verification of numerical diffusion models as well as for normal safety analysis of the release of hazardous materials.

List of Publications

None

TITLE: Cloud model (1-D) sensitivity to vertical distribution of CAPE as measured by VAS

INVESTIGATOR: G. D. Emmitt, Universities Space Research Assoc.
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SIGNIFICANT ACCOMPLISHMENTS FY-83:

The physical retrievals of VAS soundings as performed by the University of Wisconsin are constrained to account for the total heat energy in the atmospheric column. The objective of any retrieval method is to obtain the best guess of how that energy is distributed. Often the VAS sounding will be generally too cool above 500 mb and too warm below or vice versa. However, the total energy appears to be consistent with comparable rawinsondes. As a parallel effort with the ongoing MSFC's VAS evaluation program, a study was conducted to see how sensitive the precipitation production parameterization in two cloud models (Wisner-Orville and Simpson-Wiggert) were to the vertical distribution of Convective Available Potential Energy (CAPE). The current results of the model study show that for maritime clouds there are small ($\approx 20\%$) differences in precipitation production between the extreme distributions of CAPE. For continental clouds, factors of 2-3 are not uncommon when similar CAPE profiles are used. These results are based on only one set of atmospheric profiles and therefore are not conclusive or general. Also, we are just beginning to bring the VAS soundings together with the 1-D models in enough cases to start looking for useful generalizations.

CURRENT AND FUTURE FOCUS OF RESEARCH:

To obtain a useful set of cloud model experiments, a broad range of general atmospheric conditions need to be simulated and examples of real data drawn from the archives of VAS soundings and associated convective development. The two cloud models presently running on MSFC's computers have been recently modified to work with a combination of VAS soundings and surface temperatures and dew points.

TITLE: Influence of coherent mesoscale structures on satellite-based Doppler lidar wind measurements

INVESTIGATOR: G. D. Emmitt
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SIGNIFICANT ACCOMPLISHMENTS FY-83:

Work has continued on the development of a computer simulation model for evaluating sampling strategies required to obtain useful winds from a satellite-based Doppler lidar. The emphasis of this modelling effort has been upon the impact of sub-synoptic scale (usually ageostrophic) wind phenomena on the estimation of the global geostrophic wind field.

To date, the model has used the case of a low level jet to examine the performance of various lidar shot patterns and densities. In general, the largest errors in the global wind estimate are obtained when an appropriate cloud field is superimposed on the wind field, resulting in a sampling pattern that is biased toward the clear air regions and thus not permitting the sub-grid (<300 km) scale circulations to be averaged out.

CURRENT FOCUS OF RESEARCH:

A proposal entitled "Influence of coherent mesoscale structures on satellite-based Doppler lidar wind measurements" has been submitted to NASA Headquarters, requesting support for a study which would include looking at the lidar scanning requirements in the presence of mesoscale phenomena such as sea breezes, hurricanes, boundary layer gravity flows, etc. The goal of that proposed work is to put some realistic bounds on the magnitudes of expected errors in the vicinity of frequently occurring flow phenomena that are often associated with severe weather events.

PLANS FOR FY-84:

Future computer simulations will be carried out with the support requested in a proposal submitted to NASA (OSSA) in April 1983.

TITLE: Analysis of Lidar, Radar, and Satellite Measurements
on Severe Thunderstorms and Their Environments

Research Investigators:

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Significant Accomplishments to Date in FY-83:

Work on the analysis of the environment of the storm of 30 June 1981, viz, the study of the evolution of wind, temperature, and moisture fields at the surface and aloft from surface and upper air observations has been completed. Objective analysis of lidar wind data for Flight 6 (June 30, 1981) has also been completed.

An indirect method of determining the average surface heat flux over an urban area like Oklahoma City from the vertical velocity variance at the lower-mid levels of the PBL was developed. This method is very suitable for nonhomogeneous terrain for which the surface heat flux cannot be computed from the surface-layer wind and temperature profiles using flux-profile relations.

Analysis of wind data from lidar flights on June 29, 1981 and the corresponding dual Doppler-radar data has been completed. The mean lidar winds agree well with the dual Doppler-radar data both in magnitude and direction; the standard deviation of the horizontal wind fluctuations from the lidar data seem to be uniformly higher than the radar-derived ones, probably because of the difference in the vertical averaging of the two systems.

The layer-averaged winds over the PBL from the dual Doppler-radar data agree well with those derived from the similarity functions predicted by numerical models for the barotropic convective PBL, supporting the hypothesis of Arya and Wyngaard (JAS, 1975).

Focus of Current Research Activities:

Tests are being run to examine the influence of drift angle delay on the calculated lidar winds and to compare the structure functions of the lidar winds, the aircraft INS-derived winds, and the radar-derived winds.

Divergence, vorticity, and deformation of the wind fields from the lidar data for June 30, 1981 are being computed. Since only single Doppler-radar data are available for this day, the burden of intercomparison between radar and lidar must rest only on the wind components radial with respect to the Cimmaron radar.

Photos supplied by NASA of the clouds in the vicinity of lidar observations will be studied for any relationship between cloud forms and perturbations in the observed winds.

Computation of wind spectra from the tower as well as the dual Doppler-radar data for June 29, 1981 is under way. An effort will be made to relate observations to theoretical models of waves and turbulence in the boundary layer. We shall also compute the momentum flux profiles from the dual Doppler-radar data.

Plans for FY-84:

The analysis of all the lidar data collected during June 29 - July 2, 1981 and the corresponding radar and tower data will be completed. Some of the results for June 30, 1981 will be presented at the 21st Conference on Radar Meteorology in Edmonton, Alberta during September 1983; the results on the intercomparison of lidar and radar wind data for June 29, 1981 will be presented at the URSI/USNC-F meeting to be held at San Francisco during August 31-September 2, 1983.

Recommendation for New Research:

There is an urgent need for the study of the downburst phenomenon in connection with aircraft landing and take-off safety, and airborne Doppler lidar in conjunction with ground-based Doppler radars can be advantageously used for this.

Also of interest is the collection of data in the vicinity of supercell-type severe storms commonly seen in Oklahoma during Spring. The Doppler lidar is also well suited for making observations around other features associated with severe storms: fronts, drylines and their mutual intersections, before, during and after severe storm initiation, and the gust fronts and flanking lines that are a part of mature storms.

List of Publications Prepared since June 1982:

- Bluestein, H. B., McCaul, E. W., Jr., and D. Fitzjarrald:
"Airborne Doppler Lidar and Ground-based Doppler Radar Observations of a Thunderstorm in Oklahoma" - to be presented at the 21st Conference on Radar Meteorology, Edmonton, Alberta, Sept. 1983.
- Doviak, R. J., Rabin, R., and A. J. Koscielny, 1983:
"Doppler Weather Radar for Profiling and Mapping winds in the Prestorm Environment". IEEE Transactions on Geoscience and Remote Sensing, GE-21, 25-33.
- Eilts, M. D., Fitzjarrald, D., Sundara-Rajan, A., and R. J. Doviak: "Intercomparison of Wind Data from Airborne Lidar and Ground-based Radars" - to be presented at the URSI/USNC-F meeting, San Francisco, Aug. 31-Sept. 2, 1983.
- Sundara-Rajan, A., Eilts, M. D., and R. J. Evans: "Estimation of the Surface Heat Flux over Urban Terrain from the Vertical Velocity Variance" - submitted for Publication in Boundary-Layer Meteorology.

TITLE: Satellite Coherent Doppler Lidar Scan Techniques for Measuring Global Winds

Research Investigators: John W. Kaufman
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Significant Accomplishments to Date in FY83:

A literature search has been underway to determine methods of scanning with a satellite-borne Doppler lidar (light detection and ranging) system to obtain global winds. Various Lidar scanning methods have been discussed among John Kaufman, Robert Holland and George Fichtl, Chief ED42, and to date two preliminary scanning techniques have been computerized. The first was the circular scan method from the Shuttle at orbiting altitudes, H , of 300 to 800 km. Initially, a half-angle, α , of scanning cone of 62.5 degrees from the vertical was used. A scan period, P_s , of 57 seconds was used at first; however, all input parameters can be varied. The second scan technique developed was the elliptical projection. Here, all input variables were similar to the circular scan approach and the eccentricity, e , of the scanning ellipse was made to vary between 0.0 to 0.95. There are advantages and disadvantages related to the circular and elliptical scanning methods. As for the circular, it is less difficult to rotate the lidar beam at a constant scan angle, but there are less beam crossings (i.e., wind velocity volume samples) in the altitude range of ground level to 100 km where favorable velocity resolution is required. The preliminary assessment of the elliptical method shows better beam crossings at the desired altitudes but the elliptical scan pattern may be difficult due to scan hardware design and engineering problems.

Current Focus of Research Activities:

I. NMC Activities

Through discussions with Dr. Fichtl, Chief ED42, and from a review of the WINDSAT Report (a satellite-borne lidar wind profiling system), John Kaufman learned that the National Meteorological Center (NMC) organized a scientific group to investigate methods to acquire wind from orbiting platforms. From a request by letter to Dr. Ronald D. McPherson (NMC), we received the draft of the minutes to the workshop held at the National Meteorological Center on February 14-15, 1983. This workshop was to discuss the design of experiments to simulate and evaluate possible future observing systems as the satellite-borne lidar wind measurement system. Participants at the workshop were from the following agencies:

1. European Center for Medium Range Weather Forecasting
2. Australian Environmental Sciences

3. Goddard Laboratory for Atmospheric Sciences
4. United Kingdom Meteorological Organization
5. Geophysical Fluid Dynamic Laboratory, Princeton, NJ
6. American National Meteorological Research Council
7. Naval Environmental Weather Prediction Research Facility

According to the minutes to the February 14-15, 1983 workshop, the next workshop of this group will be held in late 1983. Our plans are, at least, to be on the NMC distribution list to receive the minutes to their meetings and to receive their technical reports on satellite-borne lidar for measuring global winds and lidar scanning techniques.

II. In-house Research and Lidar Scanning to Measure Global Wind from an Orbiting Platform

As for the circular and elliptical projection lidar scanning programs developed in-house, the next step is to tabulate the lidar beam crossing locations, altitudes, times, etc., and document the reasonable results.

The literature search on satellite-borne lidar global wind measuring technology will continue, and we plan to coordinate with other organizations on this matter.

Plans for FY84:

To document satellite-borne Doppler lidar global wind measurement scanning techniques as discussed above. Also, to investigate other possible methods of scanning.

Recommendations for New Research:

1. Request to become an active part of the National Meteorological Center Workshop on the Design of Credible Simulation Experiments (Attn: Dr. Ronald D. McPherson at NMC).
2. Develop new orbital lidar wind measurement scanning methods in-house, other than the circular and elliptical projections.
3. Keep abreast with the advancements being made, on this scanning problem at NCAR, NOAA, NSF, other NASA centers, etc.

Publications to Date: None

MESOSCALE RESEARCH

TITLE: AUTOMATED MESOSCALE WINDS DETERMINED FROM GOES SATELLITE IMAGERY
AND AVE/SESAME/VAS DATA

RESEARCH INVESTIGATORS: Gregory S. Wilson
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(205) 453-2570

Robert J. Atkinson
General Electric
Huntsville, AL 35805

SIGNIFICANT ACCOMPLISHMENTS FY83:

An automated technique for timely and accurate calculations of mesoscale winds using GOES satellite imagery has been developed and tested on an extensive case-study data sample (see example in Fig. 1). This technique calculates cloud pattern motion in sequences of images using template registration within image subscenes. Feature selection is done objectively to ensure that motion calculations are height assignable and are representative of the actual wind. Successful comparisons have been made between the "automated" winds and those 1) measured by the AVE IV special rawinsondes, 2) calculated by single pixel tracking at MSFC and on the AOIPS system at GSFC. In addition, the patterns and features of automatically computed cloud winds are very similar to manually-tracked cloud winds leading to consistent and dynamically meaningful divergence and vorticity distributions (see Fig. 2).

Major accomplishments have been recently made in three areas:

1) Technique Development and Data Preprocessing to;

- objectively "quality control" vector selection
- filter and clean-up "window channel" images for better height assignment

2) Diagnostic Evaluations

- There is an inverse relationship between vector spatial resolution and "image-pair" time difference
- The higher the spatial resolution of the wind vectors, the more consistent are the derived spatial and temporal divergence/vorticity fields in relation to the evolving cloud structure.
- The automatic cloud wind system can generate unique meso- β (20-50 km) resolution wind and kinematic fields that are temporally consistent (even every 5 minutes) and highly related to subsequent cloud and thunderstorm development.

3) Real-Time/Research Testing

-Computer benchmarks have been executed on various computers (Cyber/Cray ~ 1 min.; IBM 4341 ~ 15 min.)

FOCUS OF CURRENT RESEARCH ACTIVITIES:

An independent McIDAS/WINCO file of manual wind vectors is being produced at the University of Wisconsin for comparison with the automatic winds to learn the strengths and weaknesses of each method. A search is underway to determine if the appropriate VAS data exists for testing/improving cloud height assignments and tracking water vapor patterns away from clouds.

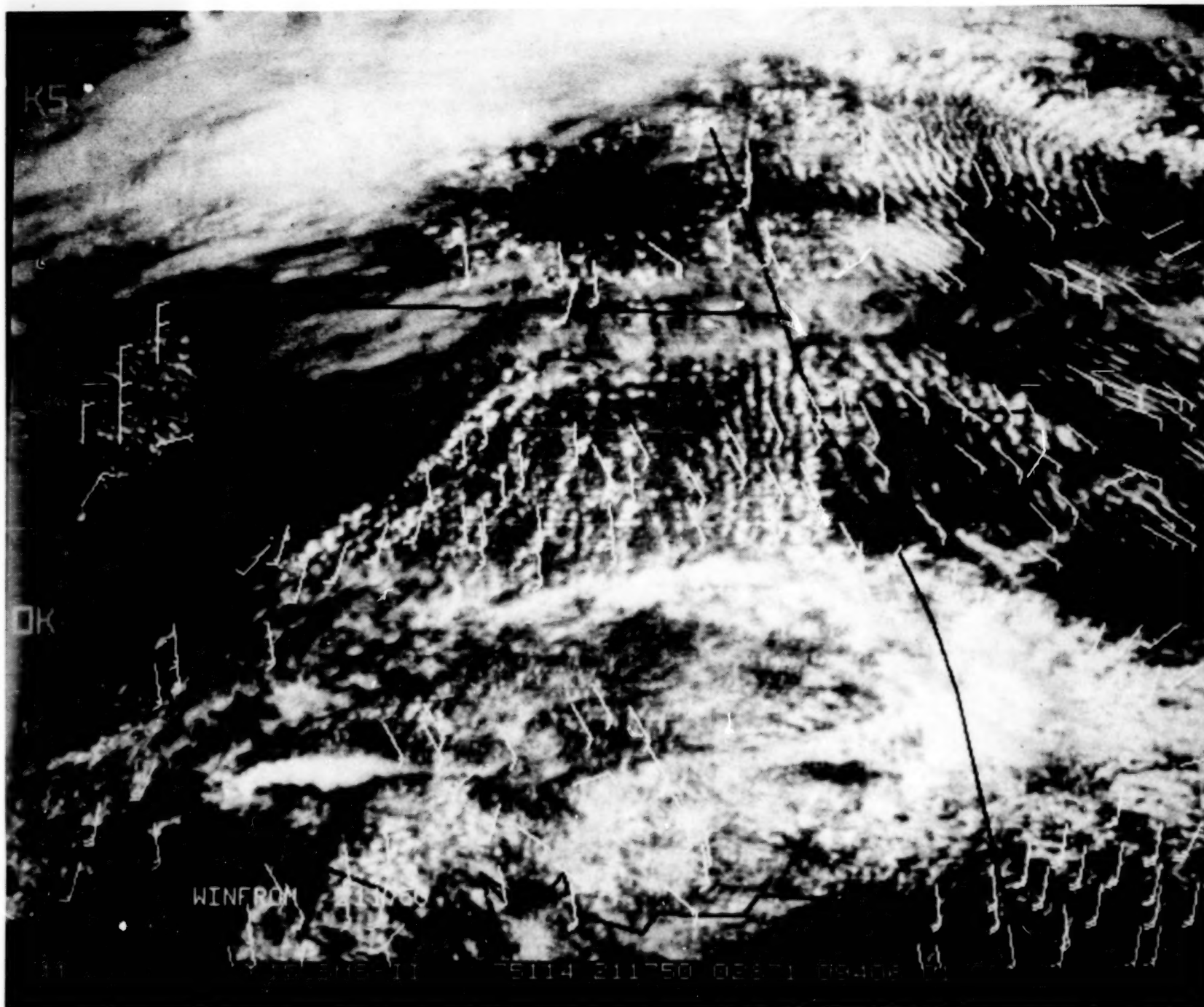
PLANS FOR FY84:

Real-time testing will begin early in FY84 using only VISSR data. The use of VAS CO₂ and H₂O imagery will also be incorporated. The VISSR technique will be submitted for journal publication.

RECOMMENDATIONS FOR NEW RESEARCH:

Since this study has shown the need for high resolution multispectral imagery (in ~ 8 spectral bands) at high time frequency (5-15 minutes), a feasibility study should be undertaken to examine the possibility of developing a dedicated Multispectral Atmospheric Mapping System (MAMS) for stabilized geostationary spacecraft for the purpose of mapping atmospheric structure and determining both mesoscale and global winds.

BEST DOCUMENT AVAILABLE





TITLE: VAS Demonstration Correlative Research

PRINCIPAL INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS IN FY83:

The approach in this research effort is to evaluate differences between VAS satellite soundings and ground truth rawinsonde data from the AVE/VAS Ground Truth Field Experiment. The time periods from 1100 GMT 6 March through 0000 GMT 7 March 1982 were used to investigate the ability of VAS sounding data to resolve mesoscale features in a stable, clear air environment. The data from 1100 GMT 24 April through 1100 GMT 25 April will be used to evaluate how well VAS soundings represent conditions important for convective storm development.

In order to eliminate time and space discrepancies between the data sets, special procedures were used to adjust the ground truth rawinsonde data. First, the rawinsonde data were adjusted to a common time at all levels to account for non-simultaneous releases, variations in the sonde ascent rate, and for the different rawinsonde and satellite observation times. The times of adjustment were determined so that the rawinsonde data were valid fifteen minutes after the beginning satellite scan time. The rawinsonde data then were analyzed to a rectangular grid centered over the mesoscale network and having a grid spacing of 38.5 km. A scan radius was selected such that roughly 98% of 450 km features were resolved and only 50% of 250 km features (twice the rawinsonde spacing) were maintained in the gridded fields. The gridded basic parameters included geopotential height, temperature, dewpoint temperature, and mixing ratio. From these data, grids of thickness, precipitable water, relative humidity, and layer means of each parameter were derived.

The satellite sounding data for the 6 March period were objectively analyzed to an identical set of grids using the same weighting and filter functions. The gridding of the data has eliminated spatial discrepancies between the sounding locations and also provides data sets with the same frequency response to the mesoscale features. Identical parameters were calculated with the satellite data as were with the ground truth rawinsonde data. Two satellite data sets have been utilized for the March experiment period. The first satellite data set was provided by the NESS scientists at the University of Wisconsin. These soundings were produced with an operational physical retrieval algorithm with LFM data being used as first guess values.

The second VAS sounding data set was provided by Goddard Space Flight Center. Their algorithm is statistical in nature and used 1200 GMT and 0000 GMT NWS rawinsonde data to develop their training data base.

A statistical evaluation of the gridded satellite data has been performed by computing the mean difference, standard deviation, and root-mean-square (RMS) discrepancy between each gridded satellite data set and the ground truth data for both basic and derived parameters. Figure 1 shows the mean temperature difference over the mesoscale grid as a function of pressure for the first five observation times on 6 March 1982. Rather large biases exist between the rawinsonde and satellite grids in various layers of the atmosphere. A warm bias ($T_{RAO} < T_{SAT}$) occurs in the lowest layer of the atmosphere. A cold bias ($T_{RAO} > T_{SAT}$) is present between 800 mb and 600 mb in both sets of satellite data. This pattern in the lower atmosphere is due to the smearing of the strong low level inversion by the broad VAS weighting functions. A similar problem develops in the middle and upper troposphere when the tropopause lowers down on the frontal zone by 1745 GMT creating a strong stable region around 400 mb. Large warm biases exist below this level. It is interesting to note that the bias patterns are very similar for the physical and statistical retrieval methods. The magnitude of these biases can be quite different however. From these profiles themselves, there is no clear indication that one particular scheme is consistently better than the other. On one hand the physical scheme maintains a more consistent bias trend. With time, however, on the other hand the magnitude of biases from the statistical method change sign but might be smaller in this example.

Table 2 shows the mean dewpoint temperature difference between the rawinsonde and satellite grids. Unlike the temperature differences, these profiles indicate different patterns of biases for each retrieval algorithm. The physical scheme seems to show a consistent negative (warm, moist) bias in the lower levels. The statistical method exhibits smaller dewpoint biases with a less pronounced trend or pattern. This along with results from other moisture parameters might indicate that better moisture representation is accomplished with the statistical retrieval algorithm.

CURRENT FOCUS OF WORK:

Current efforts are being made to further understand the significance of the statistical results so far, especially in regards to the statistically retrieved data set since we have only obtained them recently. Further calculations are underway to investigate the horizontal structure represented by the VAS soundings by calculating gradients and time change grids of the

basic and derived parameters. This will address the issue of the relative accuracy of VAS data rather than the absolute differences in the gridded fields.

FUTURE PLANS:

The accomplishments outlined above and the current efforts describe the differences between the satellite and ground truth rawinsonde data for one experiment period. It is becoming obvious that discrepancies between the data sets may depend heavily on the synoptic situation. A similar evaluation is therefore planned for the 24-25 April 1982 experiment period utilizing VAS sounding data provided by NESS at the University of Wisconsin. This case represents completely different atmospheric conditions and it is expected that satellite sounding biases be different. Other tasks subject to investigation include evaluating the improvement of the physical VAS retrievals beyond the first guess profiles, an investigation of the percentage bias between rawinsonde and satellite data due to the point and volumetric measurements of the two systems, and a study of the structural content of VAS data in relation to the visible, infrared, and water vapor satellite imagery.

PUBLICATIONS AND PRESENTATIONS:

1. AVE/VAS Ground Truth Field Experiment and Preliminary Results. Abstracts from the AGU Spring Meeting, June 1982, Philadelphia, PA.
2. AVE/VAS Experiments: Synoptic Summary and Preliminary Results. VAS Research Review, GSFC, 15-17 July 1982, Greenbelt, MD.
3. VAS Demonstration Correlative Research, with J. R. Scoggins, 1982 Atmospheric Processes review, NASA/MSFC, Huntsville, AL, p. 67-69.

Figure 1.

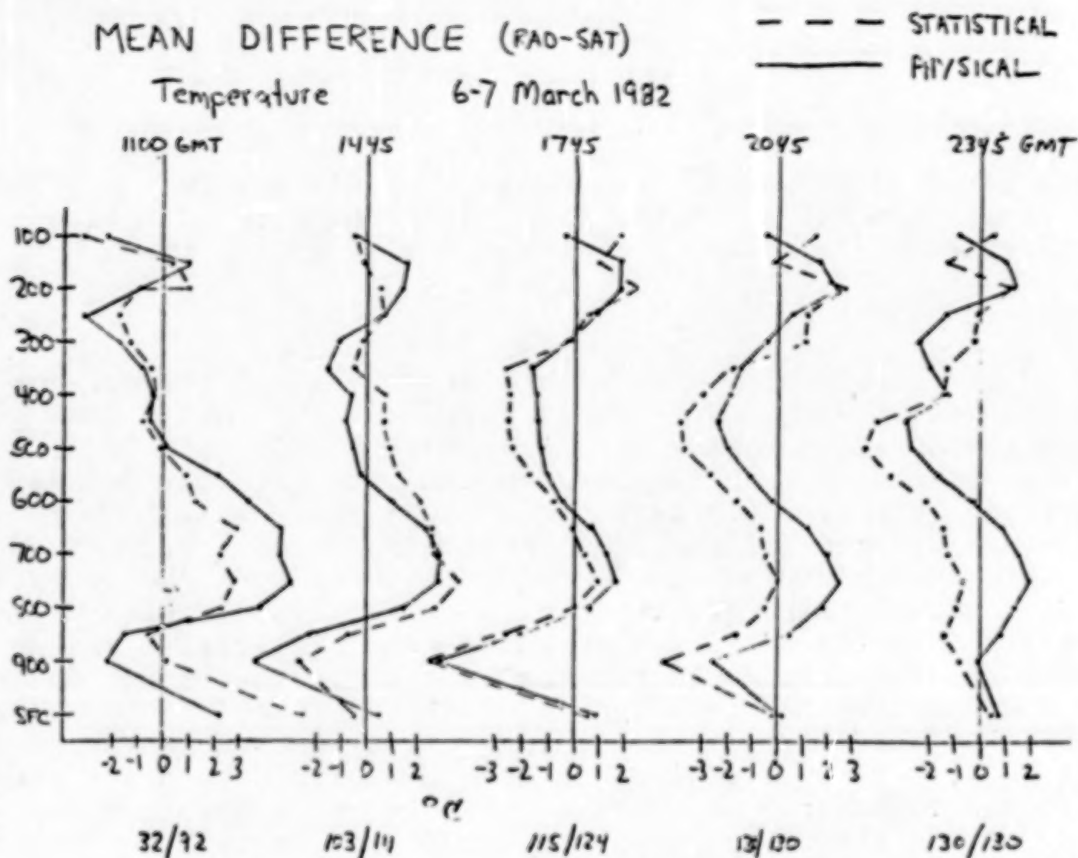
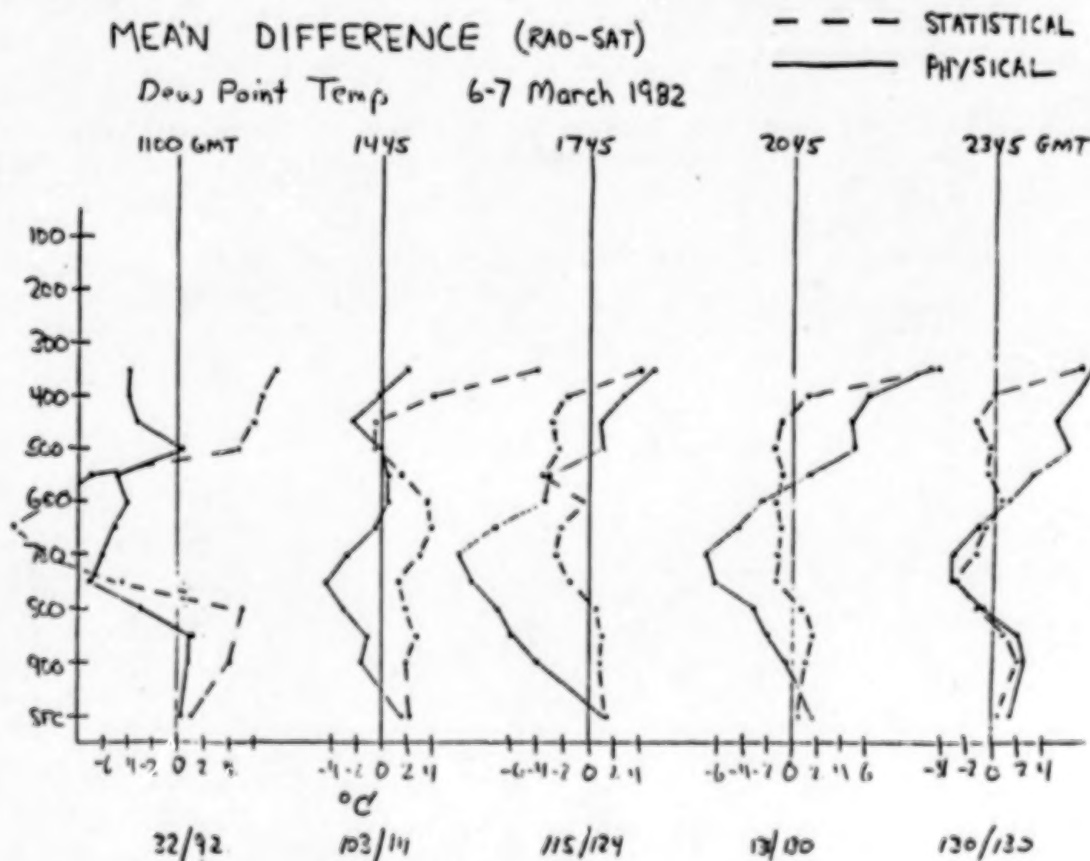


Figure 2.



TITLE: Severe Storm Nowcasting with VAS and Radiosonde Soundings

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-83:

A severe storm nowcasting scheme using either VAS vertical temperature soundings or radiosonde soundings was implemented on the McIDAS computer system. Previously done "Non-linear Graphical Regression" equations using NOAA-6 polar orbiting satellite soundings were updated for use with soundings derived from the VAS instrument during 1982.

VAS soundings processed beginning at 13:30, 14:30, 18:30, and 20:30 Z at the University of Wisconsin NESS Development Laboratory were sent in near real time to Kansas City for evaluation. Also evaluated and documented several times daily were the corresponding probabilities of severe storms according to the "graphical regression" technique, which non-linearly correlates severe storm parameters with the probability of severe storms. So far, verbal feedback from this program to display radiosonde and VAS derived severe storm probabilities has been quite positive.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The graphical regression nowcasting technique for severe storms was developed using several shortcuts. The "rough" log (as opposed to the "smooth" log, which is available later and is more complete), was used to make the method operational sooner. Several statistical "devices" can be refined for improvement of the regression equations. Sizes and division of class intervals, stepwise predictor selection, and other statistical parameters will be adjusted to "fine tune" the graphical regression technique.

PLANS FOR FY-84:

It is the feeling of the investigator that a statistical regression technique can be used to understand processes in the atmosphere, especially if the predictors are physically meaningful. With the relatively high horizontal resolution of the VAS soundings, one should be able to better depict the structure of short waves and "tongue" features associated with severe storms. In addition to improved nowcasting results, it is hoped that parameterization of 2 and 3 dimensional structures will result in an improved feeling for the actual scales of features that are observable by the VAS instrument.

RECOMMENDATIONS FOR NEW RESEARCH:

On many occasions the VAS satellite has observed significant changes in stability during the day, which have preceeded by 2-4 hours occurrences of severe storms. An example is shown in figure 1. The probability of severe storms, due largely to the stability index, increased dramatically during the day of April 28, 1983, along different portions of a strong cold front at different times of the day.

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1430Z VAS DATA

1830Z VAS DATA

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Title: Storm Environment Interactions Determined from AVE-SESAME and AVE-VAS Data

Principal Investigator: Henry E. Fuelberg
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Saint Louis University
St. Louis, Missouri 63103
(314) 658-3121

Contributors: Carol Belt, Matt Printy, Mike Remeika, Mark Ruminski

Significant Accomplishments to Date in FY-83:

Our goal is to better understand atmospheric conditions that produce severe local storms and how these systems, once formed, alter their surrounding environments. Our focus is on subsynoptic-scale interactions. Thus, we make extensive use of special rawinsonde and satellite data from AVE-SESAME and the AVE-VAS Field Experiment.

1) Our diagnostic study of the AVE-SESAME V period (20-21 May 1979) is virtually complete. This investigation has been especially useful because the meso β -scale rawinsonde data are at 75 km spacings and 1.5 or 3 h intervals which is similar to that of VAS soundings which we will soon be using in upcoming research. Analyses have included descriptions of thermodynamic and kinematic variations during the 24 h period along with kinetic energy budget calculations. Our major finding is that meso β -scale storm-environment interactions are very pronounced and are similar in character, but more intense, than those observed near Mesoscale Convective Complexes on the synoptic scale. Figure 1 shows that terms of the kinetic energy budget were greatest near the time of maximum convective activity (2130 GMT 20 May).

2) We have made major progress toward establishing the utility of computing boundary layer winds from satellite-derived thermal data. Winds in the lowest 1600m AGL are being diagnosed via thermal wind and Ekman relations similar to those contained in the Air Force's Boundary Layer Model. Winds obtained from TIROS-N soundings (Fig.2) have compared very favorably with corresponding values from concurrent mesoscale rawinsonde thermal input during AVE-SESAME II (19-20 April 1979). Both sets of thermally-derived winds show good agreements with the observed winds. Based on this single period, the technique shows promise as a new use for satellite technology; however, more case studies involving different synoptic situations are needed for conclusive verification.

3) We are continuing to investigate the Red River Valley tornado outbreak (10-11 April 1979, AVE-SESAME I). Our current focus is on the role that latent heat release played in the development of upper level jet maxima near the convective area. Values of latent heat have been calculated using the Kuo parameterization technique. We now are evaluating the radiation and sensible components of the total diabatic effect to determine whether these are as pronounced as the latent heat term. Instead of using artificial cloud data that is output from the Kuo scheme, we are utilizing GOES images and surface reports of cloud cover. Once the diabatic terms are finalized, generation of available potential energy will be calculated.

Focus of Current Research Activities:

The above mentioned tasks are being concluded. In addition, a new study has just begun. As part of a cooperative effort between NASA/Marshall, NESS/University of Wisconsin, and ourselves, we are investigating the role that mesoscale VAS soundings played in describing the convective environment during the stormy period 20-22 July 1982. We are placing ourselves in a "delayed forecasting mode" to learn how

the 3 h VAS soundings might have aided forecasters on the three days. We also want to monitor changes in the atmosphere after storm development. This task promises to be an exciting new undertaking for us.

Plans for FY-84:

Our new contract will begin during Summer 1983. It will emphasize VAS radiance studies. Specifically, we will establish the information content of VAS radiances before non-unique retrieval algorithms are applied. This statistical information will be obtained primarily from structure and correlation function analyses. Data from the AVE-VAS Field Experiment will be utilized. Information content about the VAS radiances will be compared with that from retrieved VAS soundings and concurrent rawinsonde data. A second task will be to investigate ways of utilizing VAS radiances for diagnosing atmospheric wind, thermal, and moisture patterns. Fuelberg will spend his Fall 1983 sabbatical visiting NASA/Marshall, NESS/Wisconsin, and NASA/Goddard so that initial project activities will be coordinated with those at these institutions. A close working relationship will be maintained with the various groups.

Recommendations for New Research:

It is widely believed that major new advances in forecasting skill will depend on better detection and treatment of subsynoptic-scale phenomena. With the availability of VAS sounding data at the mesoscale, many investigations to understand and exploit this new data source should be undertaken. Studies that appear fruitful include information content analyses, numerous mesoscale diagnostic case studies, inclusion of VAS data into numerical models, and the assimilation of satellite and rawinsonde data into a single set that takes maximum advantage of each.

Publications Since June 1982:

- Browning, P. A., and H. E. Fuelberg, 1983: Contributions of divergent and nondivergent winds to the kinetic energy balance of a severe storm environment. NASA Contractor Report, in press.
- Fuelberg, H. E., and P. A. Browning, 1983: Roles of divergent and rotational winds in the kinetic energy balance during intense convective activity. Submitted to Mon. Wea. Rev.
- Fuelberg, H. E., and G. J. Jedlovec, 1982: A subsynoptic-scale kinetic energy analysis of the Red River Valley tornado outbreak (AVE-SESAME I). Mon. Wea. Rev., 110, 2005-2024.
- Fuelberg, H. E. and M. F. Printy, 1983: Meso β -scale thunderstorm/environment interactions during AVE-SESAME V (20-21 May 1979). Accepted subject to revision by Bull. Amer. Meteor. Soc.
- Printy, M. F., 1983: A kinetic energy study of the meso β -scale storm environment during AVE-SESAME V (20-21 May 1979). M.S. thesis, Saint Louis University, 100 pp.

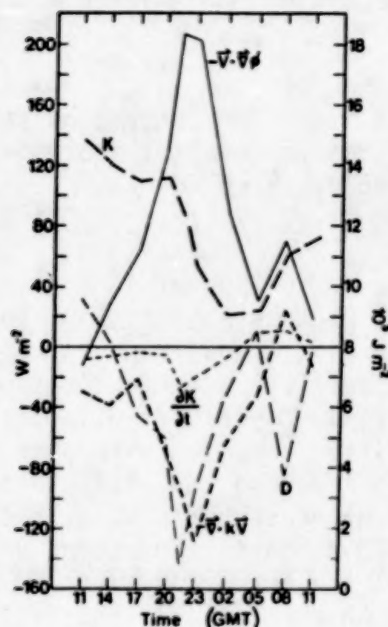


Fig. 1. Time series of meso β -scale kinetic energy budget terms integrated between the surface and 150 mb. Three hour time intervals are indicated on the horizontal axis. The AVE-SESAME I period extended from 1200 GMT 20 May - 1200 GMT 21 May 1979. Peak convection was near 2130 GMT 20 May.

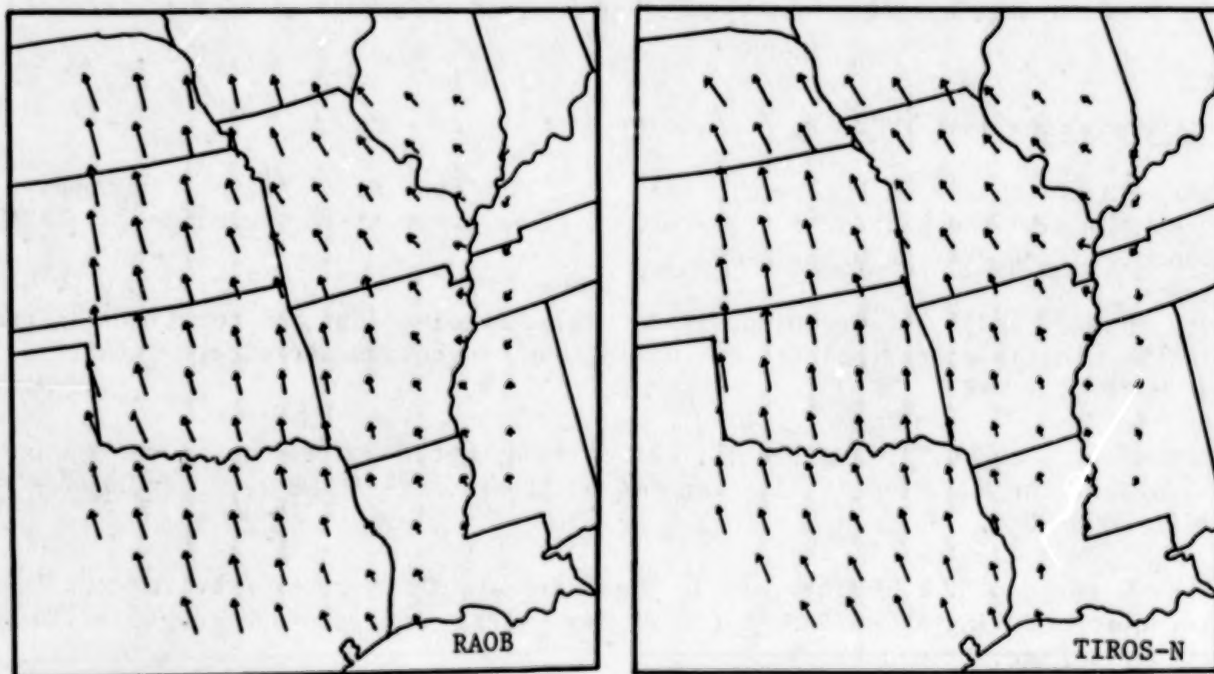


Fig. 2. Thermally derived Ekman winds at 50 m AGL on 19 April 1979 (AVE-SESAME II). RAOB data were at 1115 GMT while TIROS-N data were at 0900 GMT. The vector correlation between fields is 0.94.

TITLE: Numerical Simulation of Large Mesoscale Flows with VAS
Data

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS:

1. A version of the NCAR Graphics has been implemented on MSFC's IBM system to permit hard copy output of the Drexel University LAMPS (Limited Area Mesoscale Prediction System) code to be run at MSFC.
2. A routine called MAPPROCESS used to read model history tapes and output results via the NCAR graphics routines has been rewritten to eliminate non-portable data input/output structure and is undergoing final debugging for use at MSFC.
3. A coordinated modeling program has been established with the University of Wisconsin in support of the VAS Cooperative Program. During a planning session held at MSFC April 12, various numerical experiment strategies, prospective case studies and diagnostic efforts were discussed in relation to model simulations using VAS enhanced initial data sets.

CURRENT FOCUS OF RESEARCH:

Many tasks are proceeding in parallel at this time. Software support at MSFC is presently geared toward display of LAMPS model output both on hard copy plotting devices and in CRT. Conversion of LAMPS primitive equation code for use on MSFC hardware is scheduled to be finished in September by Don Perkey at Drexel University.

PLANS FOR FY84:

Simulation and sensitivity studies using AVE/VAS March 6 and April 24-26 data sets will be a primary goal for 1984. MSFC will concentrate initially on moisture impacts, diagnosis of mesoscale features that evolve in the model and how sensitive the results are to initial VAS data. University of Wisconsin simulations will address impacts of moisture, temperature and winds via both the Australian Subsynoptic Model (Smith and Diak) and the LAMPS model (Houghton).

ANALYSIS AND INTERPRETATION OF VAS SATELLITE SOUNDING DATA

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Significant Accomplishments to Date in FY-83:

The research has progressed on several fronts since the VAS satellite sounding data for March 6, 1982, were received in March 1983. The two principal approaches involve an assessment of the satellite sounding data by direct comparison with rawinsonde data, and by gridding both types of data and comparing the gridded data. Following is a list of specific accomplishments to date.

1. Plotted rawinsonde and satellite sounding locations on a common map for each sounding time for March 6, 1982, and identified pairs of profiles with a separation of 60 km or less.
2. Performed a statistical analysis of the paired profiles for each time. Means and standard deviations of the differences between rawinsonde and satellite soundings were computed at 100 mb intervals for each sounding time. Some biases were evident in the satellite data, but the standard deviations were relatively constant with height.
3. Prepared constant pressure charts for standard pressure levels using both types of data for both the AVE and mesoscale areas. The AVE (synoptic-scale) charts prepared from satellite data agreed quite well with those prepared from rawinsonde data, especially at the higher levels. The mesoscale charts did not compare well as expected because of the high degree of smoothing in the satellite data.
4. Cross-sections using both satellite and rawinsonde sounding data were prepared along NW-SE and SW-NE axes through the mesoscale area. The satellite fields were much smoother than the rawinsonde fields; virtually all small-scale features, such as frontal zones, were eliminated in the satellite data.
5. All paired soundings were plotted on Skew T-log p diagrams.
6. A computer program was prepared to grid the data using the Barnes technique, and some preliminary gridding performed.

Focus of Current Research Activities:

Now that much of the preliminary work has been accomplished, we have begun to concentrate on the following.

1. Perform statistical comparisons between satellite and rawinsonde

sounding data for temperature, dew point temperature, geopotential height, thicknesses, and various stability indices. Also, we hope to stratify the results to show relationships, if any, between the differences and atmospheric structures.

2. Attempt to establish the representativeness of the satellite data. This will be done by determining differences in the frequency (wave number) content of the two types of profiles, and by averaging the rawinsonde data over grid areas, both horizontally and vertically, in order to simulate the satellite data. The mathematical approach is under development.

3. Differences between satellite and rawinsonde gridded data are being analyzed in a similar manner as described in 1 above.

Plans for FY-84:

Continue the analyses described above. These have barely begun and much more work remains to be done.

Recommendations for New Research:

The utility of the satellite sounding data must be explored in depth. These data are unlike the rawinsonde data, i.e., they have different spatial resolution and their representativeness is different, but can potentially be of tremendous value in analysis and forecasting in data-sparse regions particularly. However, rawinsonde data is the standard the world over, and for the satellite data to be most useful the two types of data must be combined into one compatible data set that can be used and interpreted as a single data set. This will require an examination of scale resolution, effects on the initialization of numerical models, specifying limitations in the use of the data, and many other aspects.

TITLE: SATELLITE MICROWAVE RADIANCE CORRELATED WITH RADAR RAIN RATES OVER LAND

Research Investigators:

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Significant Accomplishments to Date in FY-83:

An empirically derived relationship between brightness temperatures measured by the Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7 and WSR-57 radar rain rates has been developed. Nine orbits of the Nimbus-7 data over the central United States have been compared with digitized WSR-57 PPI photographs. A stepwise multiple linear regression procedure was used to explore the extent to which the various channels were capable of supplying independent rain rate information. Problems due to wet land or water bodies were effectively screened out by accepting only those data with a polarization difference between vertical and horizontal 37 GHz data of less than 15°C. The radiation emitted from the land surfaces was obtained from the longer wavelength 21 and 18 GHz. These longer wavelengths not only had less attenuation by the rain drops, but also had larger fields of view than the 37 GHz. Since the rain cells filled only part of the field of view, these longer wavelengths effectively provided information on ground emittance. The rainrates were approximately linearly related to the microwave data at 37 GHz. The regression results were applied to an independent SMMR data set which resulted in a 0.80 correlation coefficient between the radar derived rain rates and the SMMR rain rates. Images of the SMMR rain areas look surprisingly similar to images of the radar data.

Focus of Current Research Activities

The empirically developed relationships between SMMR data and radar are being extended to other seasons. The use of visible and infrared GOES data is being investigated as a means of providing additional independent data which could improve the SMMR rainfall relationships.

Recommendations for New Research

It appears that a multichannel microwave radiometer with fields of view larger than the precipitating cells is necessary to derive rainfall rates over land. The large field of view results in a requirement for a relatively small microwave antenna. A study should be made using high quality digital radar, such as was available during SESAME, and a degraded field of view of SMMR data to see if rainfall rates can be derived from the large fields of view which would be obtained from a geostationary satellite with a modest microwave antenna.

List of Publications Prepared since June 1982:

Spencer, R. W., W. S. Olson, R. Wu, D. W. Martin, J. A. Weinman, and D. A. Santek. "Heavy Thunderstorms Observed Over Land by the Scanning Multichannel Microwave Radiometer." Submitted to J. Appl. Meteor. (1983)

Spencer, R. W., D. W. Martin, B. B. Hinton, and J. A. Weinman. "Satellite Microwave Radiance Correlated with Radar Rain Rates Over Land." Submitted to Nature (Feb. 1983)

Spencer, R. W., B. B. Hinton, and W. S. Olson. "Nimbus-7 37 GHz Radiances Correlated with Radar Rain Rates over the Gulf of Mexico." Submitted to J. Clim. and Appl. Meteor. (April 1983)

DIAGNOSTICS OF SEVERE CONVECTION AND SUBSYNOPTIC SCALE AGEOSTROPHIC CIRCULATIONS

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The purpose of this research is to study the forcing of conditions favorable for the development of severe weather through examination of mass-momentum adjustment, latent heat release, and boundary processes using numerical model simulations and the AVE-IV data set.

Significant Accomplishments

Since FY-83 commenced, a slate of 36-hour simulations has been made using the hybrid isentropic-sigma coordinate model in order to compare the effects of pseudo-geostrophic vs. geostrophic initialization of the wind field, viscous vs. frictionless conditions, and dry vs. moist conditions.

Among the differences noted in runs where the winds are initially geostrophic (G) as opposed to runs with pseudo-geostrophic initial winds (PG) are: (i) the region of low level momentum convergence stretching from southwest to northeast beneath the zonal jet streak is somewhat less coherent in G; (ii) the cross-stream ageostrophic wind at the jet entrance and exit regions is significantly more stable in PG, particularly during the first 12 hours. Combining viscosity and ground stress with pseudo-geostrophic initialization results in low level fields of momentum convergence which are markedly more coherent than in the case which includes viscosity but was initialized with geostrophic winds.

Runs including latent heating have also been made. All cases produce rainfall below the right entrance and left exit region of the jet streak as expected. However, the rainfall amounts of 1 to 1.5 mm are quite small.

Focus of Current Research

Currently, certain variations in the model's initial conditions are being made. A wave of low level moisture (similar to a moist tongue of Gulf air) is being inserted. Also, parameterization of the ground stress will be varied to check the response of low level convergence and upward motion. In one experiment, the initial atmosphere was saturated below 800 mb. These initial conditions in combination with pseudo-geostrophic initialization resulted in immediate precipitation that continued during the 36 hours of simulation. Realistic simulation of rainfall during the early time periods of model integration is crucial for future applications to the meso-scale.

Plans for FY-84

In future numerical experiments, initial analytic conditions will be varied in order to study the roles of such fundamental hydrodynamic characteristics as static stability, vorticity, and vertical wind shear in the atmosphere's response to jet streak forcing. Also, a large scale wave will be embedded into the basic flow in order to examine the significance of curvature effects and scale interaction. Doubling of the horizontal resolution to a grid spacing of 137.5 km will soon be effected. Finally, in diagnostic studies the ageostrophic wind will be decomposed into its so-called pseudo-geostrophic and apseudo-geostrophic parts. This breakdown largely isolates along-stream components modified by the relative vorticity and cross-stream components as well as components due to latent heating, friction, and non-steady effects. Such a perspective of ageostrophic flow will be useful in accurately describing the role of the jet streak in forcing meso-scale mass and momentum adjustments.

Recommendations for New Research

Upon completion of the previously outlined modeling work, an important next step will be to examine the potential utility of assimilating satellite and conventional observations along with pseudo-geostrophic initialization into predictions at the meso-scale. Determining the practical limitations of these data in initialization and prediction for the meso-scale will be particularly important.

List of Publications Prepared since June 1982:

Johnson, D. R., and L. W. Uccellini, 1982: A comparison of methods for computing the sigma coordinate pressure gradient force for flow over sloped terrain in a hybrid theta-sigma model. Accepted for publication in Monthly Weather Review.

Keyser, D. A., and D. R. Johnson, 1982: Effects of diabatic heating on the ageostrophic circulation of an upper tropospheric jet streak. NASA Contractor Rep. 3497, prepared for Marshall Space Flight Center under Contract NAS8-33222, [NTIS 8216658], 121 pp; also submitted to Monthly Weather Review.

Schlesinger, R. E., L. W. Uccellini, and D. R. Johnson, 1982: On the effects of the Asselin time filter upon numerical solutions to the linearized shallow-water wave equations. Accepted for publication in the Monthly Weather Review.

Title: Statistical Structure of Convective Periods Derived from Satellite and Ground Based Data

Investigators: Paul J. Meyer
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Significant Accomplishments to Date in FY-83:

Statistical structure and correlation function analyses are useful tools for quantifying atmospheric gradients, gradient variability, and data uncertainty. Computations have been completed on rawinsonde-derived values of geopotential height, temperature, wind, and moisture for the AVE-SESAME I period (10-11 April 1979, Red River Valley tornado outbreak). Three major tasks were performed on the AVE-SESAME I data during FY-83: calculation of anisotropic structure and correlation functions, a sensitivity analysis, and correlation function calculations. All computations included sonde drift and were performed at four levels--850, 700, 300 and 200 mb. A manuscript describing these results is being prepared for the Journal of Climate and Applied Meteorology.

Anisotropic structure calculations yield information about mean orientations of gradients in a field. Results indicate that the AVE-SESAME I period contained highly directional gradients. Figure 1 shows the mean orientation of temperature gradients at 850 mb. As can be seen, strong gradients lie along a north-south axis, while weaker values occur in a west-east orientation.

A sensitivity analysis was performed to quantify possible effects of input data errors and computational procedures on the structure calculations. Three factors were investigated: 1) data errors, 2) missing data, and 3) varying the separation interval used to calculate structure. These efforts have proven highly valuable, and have allowed us to better interpret our results.

Correlation function computations also have been completed. The correlation function is the inverse of structure, and since it is normalized, it provides a ready basis for comparing the information content of different parameters (e.g., height, winds, moisture). It is especially useful for quantifying the degree of atmospheric variability occurring below specified scales of motion. Figure 2 shows temperature correlation at 700 mb. From the figure, one can see that twenty-five percent of the thermal variance occurs at wavelengths shorter than 600 km. This information would be undetected by a station network having a coarser spacing than 300 km.

Focus of Current Research Activities:

Research is underway on the AVE-SESAME V storm scale period. Average station spacing of the network was 75 km. Utilizing these data, we hope to better describe the active features of the mesoscale environment of a convective outbreak. The computations will allow us to compare our results with those of Barnes, who used data from the 1966 and 1968 NSSL mesonet to calculate structure and correlation functions. The study is preparatory to computations involving VAS sounder data, since the satellite soundings have similar spacing to that of the AVE-SESAME V RAOB network.

Plans for FY-84:

Investigation of the AVE-SESAME V storm scale period will be completed. Calculations will begin utilizing VAS sounder data from the 1982 Field Experiment. These

will be compared with co-located RAOB observations in order to assess the ability of the VAS to describe short term atmospheric variability. Additional AVE-SESAME cases may also be studied.

Recommendations for New Research:

The planned studies to statistically describe VAS-derived soundings will utilize data from the 1982 Field Experiment which did not include severe convective outbreaks. The ability of VAS to depict enhanced mesoscale gradients, associated with intense convection also should be evaluated using additional data sets.

Publications since June 1982:

None, however, a manuscript is currently being prepared for submission to the Journal of Climatology and Applied Meteorology.

BEST DOCUMENT AVAILABLE

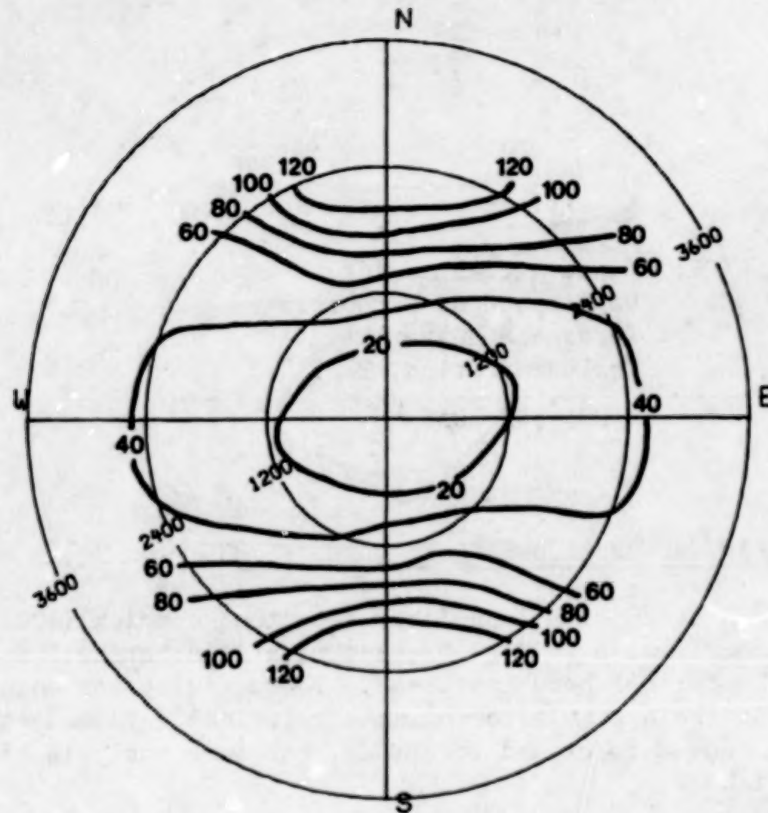


Fig. 1. Anisotropic temperature structure ($^{\circ}\text{C}^2$) at 850 mb for the period 1200 GMT 10 April to 1200 GMT 11 April 1979 (AVE-SESAME I). Concentric rings indicate wavelength in kilometers.

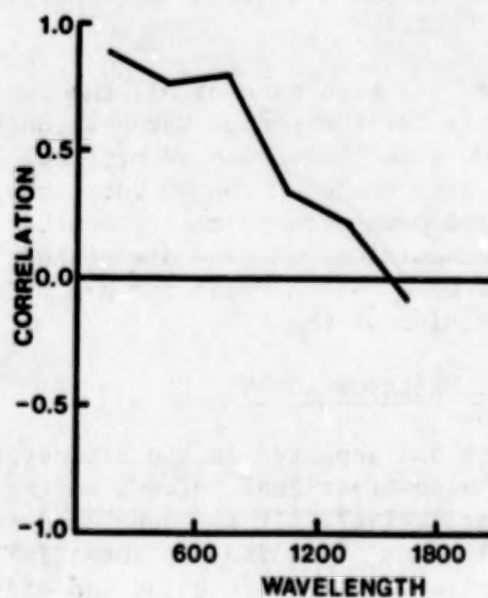


Fig. 2. Correlation function of temperature at 700 mb for the period 1200 GMT 10 April to 1200 GMT 11 April 1979.

TITLE: Investigation of the Arc-cloud Complex

INVESTIGATOR: Kenneth C. Brundidge
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SIGNIFICANT ACCOMPLISHMENTS TO DATE. FY-83

1. A study of a long-lived arc-cloud complex (ACC) started while the PI was a summer '82 visitor at the Marshall Space Flight Center has been continued. The activity has mainly consisted of the accumulation of meteorological data and satellite imagery needed to expand the study, but some analysis has been accomplished.

In this regard, upper-air soundings for six stations and at two observation times have been plotted. Sectional surface maps at one-hour intervals from 09 GMT, 17 May 1982 through 00 GMT, 18 May 1982 have been plotted. Mesoscale analyses of temperature and pressure (altimeter setting) have been completed on each of these maps. Radar reports and satellite imagery have been used for guidance while performing the analyses. A complete set of GOES-EAST satellite pictures for the period of interest has been obtained from the National Weather Service Storms Forecast Center.

2. A survey has been made of all the available GOES-EAST satellite pictures for the period March through July 1982. Several other ACC cases have been identified. From these, the case of 26 June 1982 has been chosen for study. Maps and soundings for this case have been plotted and other meteorological data has been accumulated. A graduate student has started the analysis of this case as the basis for his M.S. thesis work under the supervision of the P.I.

FOCUS OF CURRENT RESEARCH ACTIVITIES

A report has appeared in the literature of an ACC which moved through the observational network during the Line Island Experiment in April, 1967. It was concluded from the observations and calculations of equivalent potential temperature that the air mass enclosed by the arc cloud was mid-tropospheric air that had passed under the raining anvil of a Cb cloud and had

become rain-cooled but was still unsaturated. This air sank to the ground and spread out while conserving its θ_e . A calculation of θ_e values at various levels for the case at hand has been started to see if the same process may be at work.

PLANS FOR FY-84

Support will be sought for the continued analysis of the cases mentioned here plus new cases. From the analysis of a number of cases, it should be possible to develop a theory for the dynamics involved in the formation and maintenance over a number of hours of the arc cloud complex. A better understanding of the ACC dynamics also should clarify the mechanisms involved in the initiation of new convective storms in the region penetrated by the arc cloud.

RECOMMENDATIONS FOR NEW RESEARCH

1. It is recommended that VAS data be used in the study of arc cloud complexes whenever they are found to be available for the purpose.

2. From analysis of many cases, determine from the satellite imagery the signatures which indicate when and where severe storms will be initiated by the propagating arc cloud.

OUTLINE OF RESEARCH ACTIVITIES

ANALYSIS OF SATELLITE DATA FOR SENSOR IMPROVEMENT (Detection of Severe Storms from Space)

T. Theodore Fujita

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Significant Accomplishments for FY-83

The major subject being investigated under the current grant is to establish the relationship between (1) cloud-top features, and (2) storm characteristics on the earth. Simultaneous observations of a distant thunderstorm on August 9, 1982 by a Doppler radar and GOES East and West were accomplished.

Current Focus of Research Work

Three items listed below have been investigated under the FY-83 grant:

- Item (1) Stereo photography of clouds over southeast Asia by using NOAA7 (U.S. satellite) and GMS (Japanese satellite).
- Item (2) Mapping of the August 9, 1982 thunderstorm tops. A mapping technique of determining IR temperature fields at 1° intervals between +40°C and -90°C was completed. Test analyses are being conducted.
- Item (3) Photography of thunderstorm tops in August 1983 from Ames-based NASA's Lear Jet.

Plans for FY-84

Item (1) will be continued into FY-84. After the launch of GOES West, however, an attempt will be made to synchronize GOES West with GMS. GMS scan time is unchanged, while GOES West scan time will be changed so that a precise synchronization can be achieved. This project is a part of the NASA-MSC (Meteorological Satellite Center of Japan) cooperation program.

Analysis of Lear Jet photographs to be obtained in Item (3). It is expected that several sequences of cloud-top pictures will be taken over the Midwest. NASA Lear Jet will be based at Grand Island airport, Nebraska where a WSR-57 radar is available. Lear Jet photographs are

to be combined with both radar and satellite photographs.

Investigation of tornadoes and downbursts along with IR mapping of their parent clouds. This is a continuation of severe storms work. In FY-84, an emphasis will be made to determine IR temperature fields not only at thunderstorm tops but also their environment. A newly developed technique will permit us to draw 1°C isotherms around thunderstorms.

Published Papers in FY-83

- [1] Fujita, T.T. and R.M. Wakimoto (1982)
Effects of meso- and mesoscale obstructions on PAM winds obtained during Project NIMROD. Journal of Applied Meteorology, Vol. 21, No. 6, June, pp. 840-858.
- [2] Wakimoto, R.M. (1982)
The life cycle of thunderstorm gust fronts as viewed with doppler radar and rawinsonde data. Monthly Weather Review, Vol. 110, No. 8, August, pp 1060-1082.
- [3] Forbes, G.S. and R.M. Wakimoto (1983)
A concentrated outbreak of tornadoes, downbursts and microbursts, and implications regarding vortex classification. Monthly Weather Review, Vol. 111, No. 1, January, pp. 220-235.
- [4] Wakimoto, R.M. (1983)
The West Bend, Wisconsin storm of 4 April 1981: a problem in operational meteorology. Journal of Climate and Applied Meteorology, Vol. 22, No. 1, January, pp. 181-189.

Title: Observations of winter storms in New England

Research Investigators: Richard A. Passarelli
Frederick Sanders
Kerry A. Emanuel

Significant accomplishments to date in 1983.

By vertical soundings and horizontal traverses, we have shown that the coastal front is extremely shallow (about 500m deep) but very intense horizontally and that its development depends crucially on the difference in boundary-layer wind and thermal structure between land and sea. By vertical soundings and Doppler radar we have shown that major precipitation bands may arise from symmetric instability associated with strong vertical wind shear in combination with small effective static stability.

Focus of current research activities:

Analysis of data obtained during the past winter.

Plans for FY-84:

Continued study of coastal frontogenesis and precipitation bands.

Note:

NASA provided a GMD-1 rawinsonde set located at MIT and operated by students from December 1982 through February 1983 as part of our winter-storm project funded by NSF. The results of the MIT soundings, together with data from Doppler radar and research aircraft, as well as from conventional sources, is now being analyzed.

TITLE: Ground Truth Field Experiments

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Significant Accomplishments FY83:

Assist Massachusetts Institute of Technology in their field project on mesoscale structures within winter storms (December 1982- February 1983) in New England. Since important precipitation features are not adequately resolved by the routine National Weather Service data network, one of the key research goals of this experiment was developing an understanding and a predictive capability on the mesoscale. Observation of the kinematic and thermodynamic structure of these mesoscale features is a necessary step toward understanding and predicting them.

Assist National Severe Storms Laboratory in their field project on storm electricity within the 1983 spring-summer program by providing three rawin systems. One of the key research goals of this experiment is observation of the electrical emissions and examination of the feasibility of utilizing lightning signals to detect cloud-to-ground strokes in a satellite system.

Current Focus of Research Work:

The major focus for the coming months will be to continue to keep abreast of the GALE, STORM, FIRE, etc. experiments proposals; to continue refurbishing the rawin system; to identify scientific studies that can be conducted involving mesoscale as well as synoptic scale phenomena.

Plans for FY84:

To participate in any FY84 experiments approved by NASA Headquarters.

The present rawin systems are being re-worked to insure minimum problems in any field experiments using these systems.

Coordination with scientific and engineering community and assistance when necessary in the data processing and analysis of AVE/VAS sets.

Recommendations for Follow-on Research:

NASA's Marshall Space Flight Center (MSFC) participated with its rawin systems in mesoscale and storms experiments which involve mesoscale as well as synoptic scale phenomena so that developed retrieval techniques and models can be used. Determine the retrievability of atmospheric parameters based upon the combination of satellite data, ground-based data, ancillary data, and physical principles.

TITLE: INTERACTIVE METEOROLOGICAL COMPUTER SUPPORT

Research Investigator: Frederick R. Mosher
Space Science & Engineering Center
University of Wisconsin-Madison
Madison, Wisconsin 53706
(608) 262-3755

Significant Accomplishments to Date in FY-83:

The remote McIDAS interactive video terminal continues to support the meteorological research efforts of MSFC. Geostationary satellite and conventional data sets have been supplied from the SSEC archive. Minor software development efforts have been undertaken to make the McIDAS capabilities better suit the needs of MSFC's research activities.

Focus of Current Research Activities

Current development efforts involve building a lightning location data access box for the BLM network, fabrication of the Mark III McIDAS system for MSFC, and preliminary investigations into the usefulness of a 3-D McIDAS terminal.

The lightning location data access box is being built to allow near-real time McIDAS access to the location of cloud to ground lightning strokes in the western United States. The Bureau of Land Management (BLM) has an existing network of twelve lightning Position Analysers (PA) built by Lightning Location and Protection (LLP) covering the western United States. SSEC is building a data concentrator box which will ingest all twelve PA's, store the data in a buffer memory, and allow interrogation of the data base via dial in phone ports. The McIDAS will call up the lightning box, request specific times and stations and then receive the requested data for plotting and analysis. One of the ports on the lightning box will be used by LLP for a tape drive which will archive all of the lightning strokes from the BLM network. The lightning box is scheduled for installation on June 6, 1983.

The Mark III McIDAS will give MSFC a McIDAS processing capability able to support a larger user community than is possible now with a single remote McIDAS video terminal. The new system will consist of a Harris/6 computer, a new 32 frame McIDAS terminal, the old McIDAS terminal, and a communications line to the SSEC IBM McIDAS for data access. There will be a switch on the system so that the new McIDAS terminal can be attached either to the Mark III Harris/6 computer or to the SSEC IBM as a remote terminal. This will allow MSFC to take advantage of new capabilities on the IBM McIDAS which are not available on the Harris McIDAS. The Mark III Harris McIDAS will allow MSFC program development independent of SSEC, greater and faster McIDAS processing support and continued access to SSEC McIDAS developments. The Mark III McIDAS is scheduled for delivery in November, 1983.

The current investigations into the usefulness of a 3-D McIDAS terminal is centered on three themes. The first is an investigation of requirements and capabilities of other institutions in multi-dimensional

meteorological technology or related activities. The second is an upgrading of the current McIDAS 3-D capabilities to be used to demonstrate the potential usefulness of 3-D presentations of weather information. The third activity relates to the development of a generalized 3-D data structure and graphic capability on McIDAS to be used in the investigations of needs for a multi-dimensional display system for meteorological uses. This 3-D effort has just started. An interim report on the study of other institutions is scheduled for November, and a preliminary demonstration of 3-D techniques useful to meteorologists is scheduled for this winter.

Plans for FY-84

The plans for FY-84 include continued McIDAS support, scientific investigations into relationship of lightning location to precipitation and severe weather, and the conceptual design of a 4-D (3-D plus time) interactive McIDAS terminal.

TITLE: Mesoscale and Severe Storms (MASS) Data Management and Analysis System

Research Investigators: John S. Hickey, Shogo Karitani, Mike Dickerson
Atsuko Computing International (ACI)
Huntsville, Alabama 35801 (205/533-7590)

Significant Accomplishments - FY83:

DATA BASE MANAGEMENT: An atmospheric data base management software package has been developed and used extensively to convert various access disc files, making the data readily accessible to the general purpose plotting and analysis software packages.

ANALYSIS AND DISPLAY: The MASS hardware/software computer system has been successfully implemented and utilized daily by the atmospheric scientists to graphically display and analyze large volumes of conventional and satellite-derived meteorological data. Utilizing the AVE 80 task scheduler (which links the various software programs together, allowing each to share common data and user inputs, thereby reducing overhead, optimizing execution, and thus enhancing the user's flexibility, useability, and understandability of the total software capabilities), the user can process interactively various AVE-type data: (Soundings, Single Level, Grid, and Image).

Current Focus of Research Work:

Currently, the existing atmospheric software and data sets are being modified to be easily accessible and useable by the Apple III computer terminals to be installed into individual scientist's offices, which will enhance the overall research environment.

Plans for FY84:

Software Modification--

- o Continue modifications to the data base management software on the MASS computer to process the four major data types.

Hardware Modification--

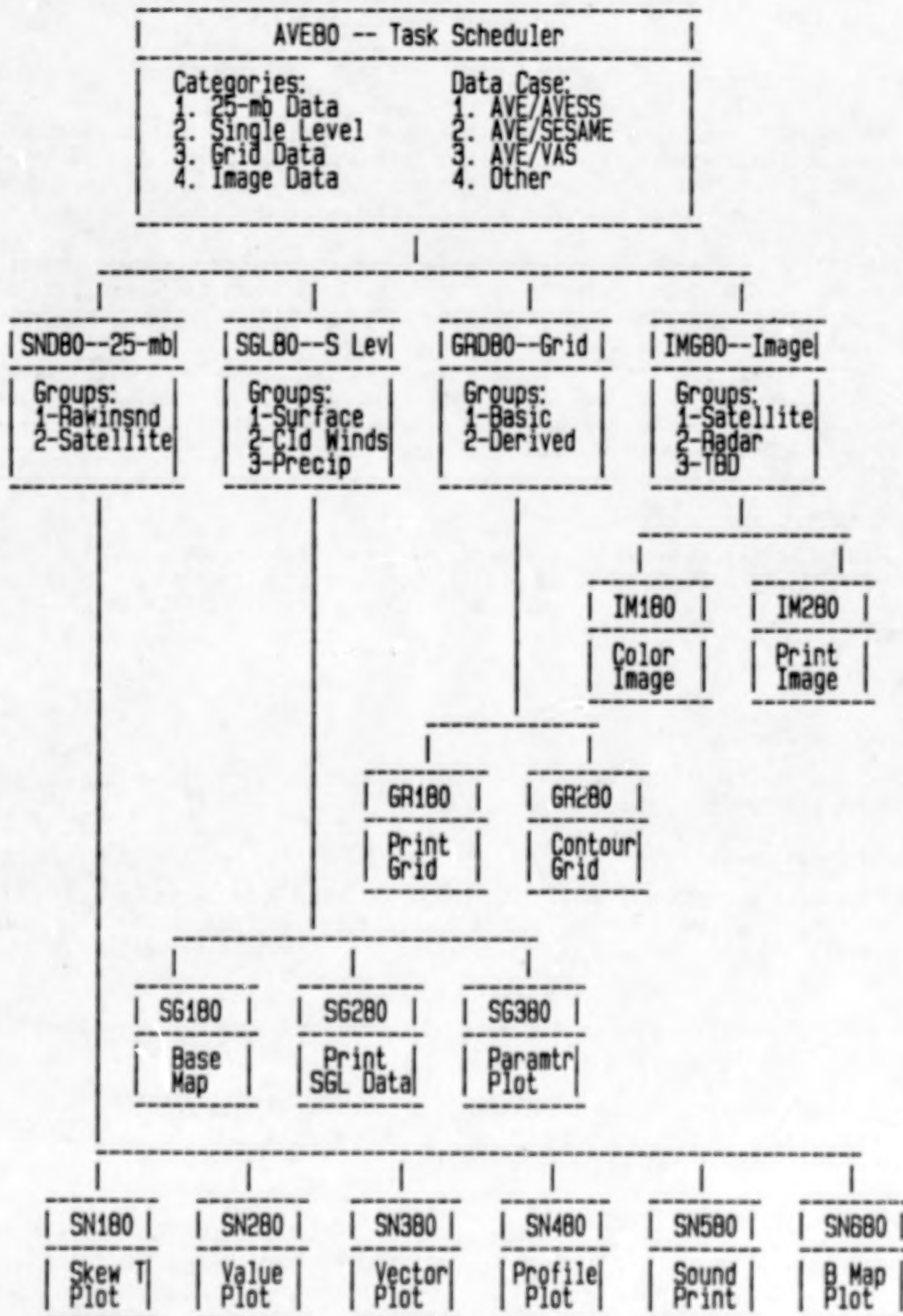
- o A Perkin-Elmer 3252 and Harris/6McIDAS computer are to be installed into our current system which will allow for interactive image-processing and numerical weather research related to the use of satellite imagery and soundings.
- o Several Apple III computer systems will be installed in individual offices, which will allow for the following:
 - Editing and job input terminal for MASS/PE-3252
 - Interactive color graphics/imaging for MASS system
 - Remote terminal via Modem/telephone link.

Recommendations for New Research:

To continue modifying the atmospheric software and data sets to provide for more capabilities via the integrated utilization of the MASS HP-1000, Perkin-Elmer 3252 and McIDAS-Harris/6 computer systems.

BEST DOCUMENT AVAILABLE

 ** MASS ANALYSIS & DISPLAY SOFTWARE **

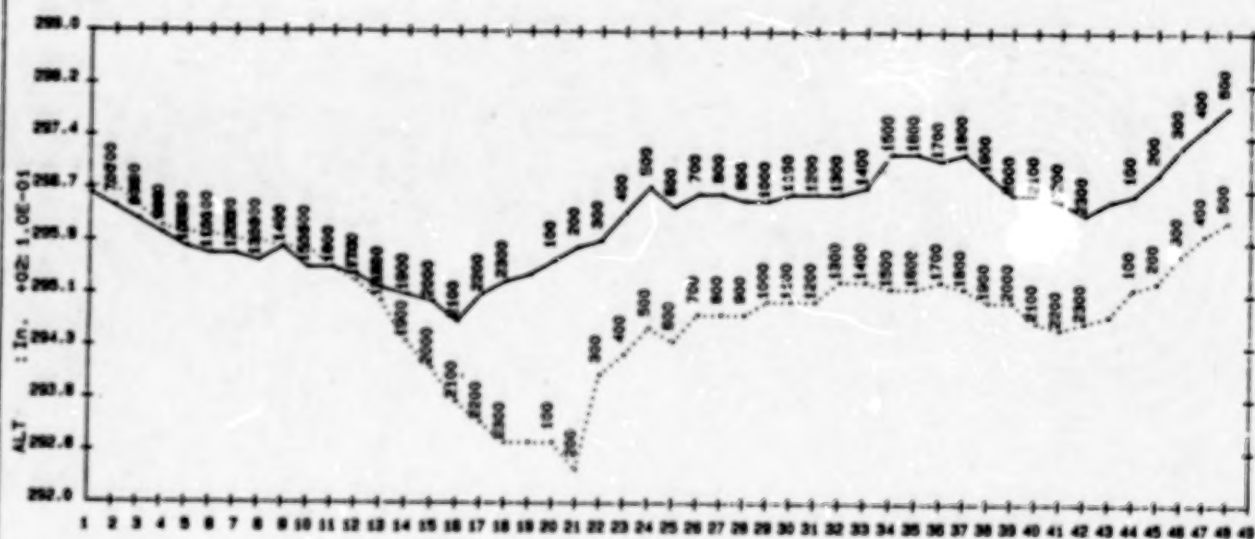


SURFACE

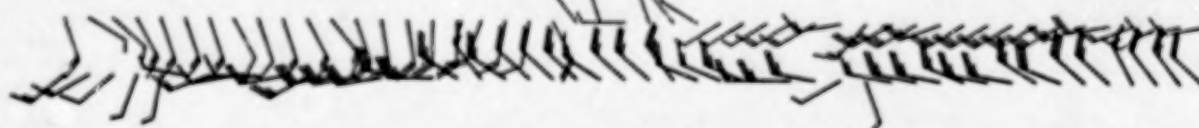
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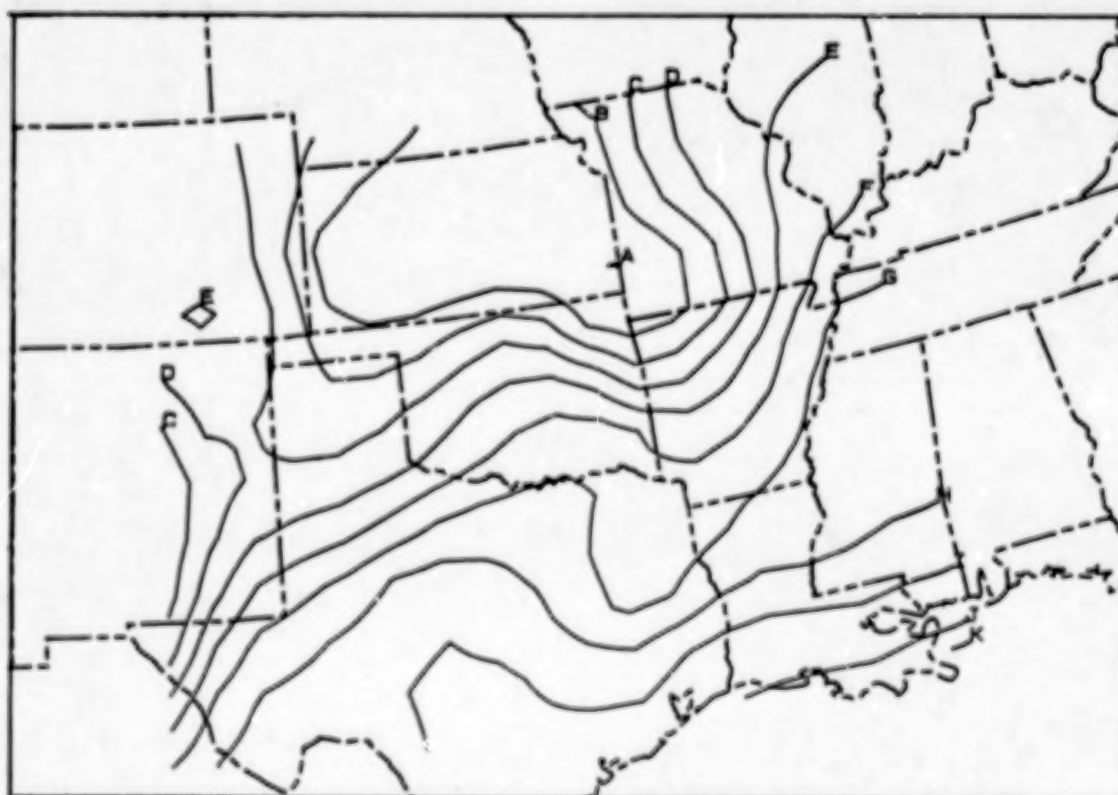
FLP



TIME/PERIOD



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**SOLAR-LOWER/UPPER ATMOSPHERIC
COUPLING RESEARCH**

Title: Solar Influence on Terrestrial Weather and Global
Lightning Patterns via Cosmic Ray Modulations

Research Investigator: Dr. John T. A. Ely
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Geophysics Program
University of Washington, FM-15
Seattle, WA 98195

Significant Accomplishments to Date in FY-83:

1. A preliminary survey has been conducted on the data tapes (finally received in 1982) for our Space Forecasting Experiment (SFEX) on the S3-4 satellite. The Air Force data processing contractor has agreed (April 1983) to provide already generated software necessary for final detailed analysis of these data for both the high latitude stratus and the global lightning investigations.
2. Canadian surface data tapes giving cloud heights and cosmic ray neutron monitor records for 14 years were obtained in late 1982. We have finally overcome format difficulties and have begun work on these tapes (to test our theory that surface data as well as satellite data can be used to predict solar influence on certain aspects of clouds, weather and climate).

Focus of Current Research Activities and Plans for FY-84:

1. Analyze the long awaited satellite and surface data for effects on the extent of high latitude winter stratus clouds in the 10 kilometer altitude region (and hence on weather and climate).
2. Analyze the satellite data for effects of solar activity on global lightning incidence and patterns.
3. Continue development of theoretical models relating climate and thunderstorm variations to atmospheric electrical effects and to solar modulation of cosmic rays.

Recommendations for New Research

1. The economical SFEX type low altitude polar orbit cosmic ray surveys (>1GV) should be done continuously over as much of two solar cycles as secondary payload space permits.
2. Complete a study of surface data as we have just begun (see above) to determine if these effects can be detected adequately without satellite sensors. (Although the surface data is more economical in that it is already being recorded, we anticipate its analysis may be more difficult).
3. Evaluate the accuracy with which high latitude cloud cover can be monitored in winter (especially over land masses) from weather satellite pictures.

List of Publications Prepared since June 1982

1. Solar Activity and Lightning Incidence.
2. Thunderstorm Electrification (2).

TITLE:

Solar Variability and Quasistationary Planetary Wave Behavior

RESEARCH INVESTIGATOR:

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Com (303) 497-5999
FTS 320-5999

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY83:

A simple model of resonantly trapped planetary waves currently being developed and tested suggests that there should be a distinct solar cycle behavior in tropospheric blocks associated with wave 1. A high amplitude, 22 year cycle in the annual number of days with blocks is clearly visible in historical German weather maps spanning 1881-1950. The peaks in the 22 year cycle closely coincide with the sunspot maxima of 1893, 1917, and 1937. Ongoing work has centered on extending this statistical study forward in time to the present.

An analysis of blocking data derived from NMC grid data and published in catalog form by the Atmospheric Environment Service, Canada, has independently confirmed that the 22-year cycle in blocking continued during the years 1946-1978. More importantly, using this data, it has been determined that this long cycle in 500 mb blocking is statistically significant at the 2 sigma level. The latitudinal distribution of winter blocks during these 32 years shows that they invariably develop within the predicted confines of the climatological planetary waveguide for wave 1. The longitudinal distribution of blocks for this same period shows a very large peak centered on the Greenwich meridian and a smaller peak near 160W. These longitudinal locations are correctly predicted by the simple steady state planetary wave 1 model under evaluation. Therefore, an analysis of the spatial distribution of winter blocks over the recent past provides good, statistically significant observational support to the theory of resonantly trapped, quasistationary planetary waves.

CURRENT FOCUS OF RESEARCH:

Research is currently focused on estimating the solar cycle variation in the ultraviolet irradiance from the Sun and determining its impact on the speed of the polar mesospheric jet in winter. The historical behavior of planetary wave 1 blocking suggests that there is a solar cycle modulation of the speed of the zonal mesospheric jet in winter which, in turn, can be physically related to resonantly trapped planetary wave states.

Simple, steady state model calculations show that a 10% variation in the climatological mesospheric jet speed can often produce a wave reflection barrier just above the stratopause. As others have theorized, the formation of such a barrier leads to a vertically resonant, amplified wave state and eventually to tropospheric blocking. Recently published models of solar cycle irradiance (e.g., Lean *et.al.*, 1982) conclude that there is a 15-30% variation in solar UV emissions over the 180-260 nm wavelengths between solar minimum and maximum. The variability in these wavelengths is of particular interest since this part of the solar spectrum is primarily responsible for the upper stratospheric ozone heating which drives the polar jet in winter. The amount of solar cycle variation being predicted by current solar irradiance models is very consistent with both wind-wave model results for trapped waves and historical statistics on tropospheric blocks.

PLANS FOR FY-84:

Work in FY-84 will concentrate on actually observing planetary wave 1 behavior in winter throughout the stratosphere and mesosphere. Particular attention will be given to the hypothesized formation of wave reflection barriers and the subsequent planetary wave response above and below such barriers. External forcing factors possibly contributing to wave reflection, e.g., geomagnetic disturbances, solar variability, etc., will be studied.

Data used in the studies will include existing satellite, rocket, and ground-based measurements of upper atmospheric zonal winds and chemistry, as well as coincident satellite observations of the near earth geospace environment.

RECOMMENDATIONS FOR NEW RESEARCH:

A comprehensive understanding of upper atmospheric winds and chemistry is needed to model and predict the behavior of externally force planetary waves in the winter stratosphere and mesosphere. Existing observations of these atmospheric variables are sparse, at best. An initiative to accurately and synoptically observe winds between 20 and 100km on a global basis needs to be undertaken. These observation can best be made from a permanent platform in space using recently developed remote sensing technology such as cross correlation spectroradiometry.

PUBLICATIONS SINCE JUNE 82:

Solar Variability and Quasistationary Planetary Wave Behavior, in Weather and Climate Responses to Solar Variations, B.M. McCormac, ed., Colorado Associated Press, 1983.

TITLE: RELATIONSHIP BETWEEN SEVERE STORM DEVELOPMENT, TROPOPAUSE HEIGHTS, AND OVERSHOOTING CLOUD TOPS

RESEARCH INVESTIGATORS:

R. J. Hung	The University of Alabama in Huntsville Huntsville, Alabama 35899 Telephone: (205) 895-6077
R. E. Smith	Atmospheric Sciences Division NASA/Marshall Space Flight Center, Alabama 35812 Telephone: (205) 453-3101
G. S. West	Atmospheric Sciences Division NASA/Marshall Space Flight Center, Alabama 35812 Telephone: (205) 453-5218

SIGNIFICANT ACCOMPLISHMENTS FY-83:

Basic characteristics of clouds associated with severe storms determined from analyses of satellite, imagery, rawinsonde observations, and Doppler sounding are: (1) Large turrets penetrating above the tropopause. (2) A large difference between the overshooting cloud top temperature and the tropopause temperature, a measure of how much the cloud has penetrated above the tropopause, in contrast to either the absolute temperature of the penetrative cloud or the height of the top of the overshooting turret. (3) A growth rate of the overshooting turret above the tropopause much greater than that for non-severe storm-associated clouds. (4) A rapid collapse of the high density overshooting turret (temperature of the overshooting turret is much colder than the surrounding air temperature) about 15 to 30 minutes before the tornado touchdown, in contrast to the dissipation rate of non-tornado-associated clouds which is much slower, allowing the cloud to persist for several hours after the turret penetrates above the tropopause and reaches its highest altitude. (6) The lifetime of no more than 3 hours, from the moment the overshooting turret penetrates above the tropopause to the touchdown of the tornado. (7) Gravity waves. Ray tracing results show that the source of these gravity waves is located at the cloud at the time the overshooting turret is penetrating above the tropopause.

CURRENT FOCUS OF RESEARCH:

Our study results from geosynchronous satellite imagery indicate that there are very few apparent differences between clouds which spawn tornadoes and those which do not during the inception and developing stages of the clouds before they penetrate the tropopause. After penetrating the tropopause, the differences between the two cloud systems are more readily discernible in satellite imagery. Our current research is focused on the mechanisms which initiate and enhance the convective cloud development before the cloud tops penetrate the tropopause.

Our current approach to determine the key parameters affecting convective cloud formation includes the analysis of the humidity ratio, vorticity, and potential temperature distribution at different heights, in conjunction with the time-dependent variation of the tropopause height.

PLANS FOR FY-84:

Our present study shows that there are some strong indications of pre-storm conditions such as the enrichment of the humidity ratio at low level (850 mb), high vorticity, unstable potential temperature profile, and low tropopause heights. The conventional rawinsonde data is only available at 12 hour intervals. AVE-SESAME data, together with rapid-scan satellite imagery, will be used to determine the parameters which initiate and enhance severe storm development.

RECOMMENDATIONS FOR NEW RESEARCH:

Our study shows that the tropopause height change may be one of the more important parameters affecting severe storm development. It is recommended that rapid-scan satellite IR imagery; vertical temperature and moisture profiles from VAS; and vertical vorticity, moisture and temperature profiles from rawinsonde and/or AVE-SESAME be used as input data in a 2-dimensional cloud model to generate a cloud for comparison with actual observations. The rate of change of the tropopause temperature will be fed into the computer model to determine the critical tropopause temperature and the rate of change of tropopause temperature which may affect the severe storm formation.

LIST OF PUBLICATIONS PREPARED SINCE JUNE 1982

1. Hung, R. J., and Smith R. E., Remote sensing of Arkansas tornadoes on April 11, 1976 from a satellite, a balloon and an ionospheric sounder array, International Journal of Remote Sensing, 4, in press, 1983.
2. Hung, R. J., Dodge, J. C., and Smith, R. E., The life cycle of a tornadic cloud as seen from a geosynchronous satellite, American Institute of Aeronautics and Astronautics Journal, in press, 1983.
3. Hung, R. J., and Smith, R. E., Case study of the March 24, 1976 Elton, Louisiana tornado using satellite infrared imagery, Doppler sounder, rawinsonde and radar observations, International Journal of Infrared and Millimeter Waves, 4, in press, 1983.
4. Hung, R. J., Liu, J. M., Tsao, D. Y., and Smith, R. E., Relationship between convective clouds and precipitation over the Qinghai-Xizang Plateau area from satellite and groundbased observations, Annales Geophysics, submitted, 1983.
5. Hung, R. J., and Smith, R. E., Detection of convective storms based on penetrative cloud top from satellite infrared and rawinsonde data, and gravity waves from doppler sounder, Cloud Dynamics, ed. E. M. Agee and T. Asai, pp. 347-362, Amsterdam: D. Reidel Publishing Co., 1982.
6. Hung, R. J., and Smith, R. E., Remote sensing of severe convective storms from geosynchronous satellite, Remote Sensing and the Atmosphere, University of Reading, United Kingdom, pp. 283-291, 1982.
7. Hung, R. J., Liu, J. M., Tsao, D. Y., and Smith, R. E., Remote Sensing of Severe Convective Storms over Qinghai-Xizang Plateau, Remote Sensing of Environment, in press, 1983.

8. Hung, R. J., and Smith, R. E., Overshooting cloud-top penetrated above the tropopause and severe storm formation, Transaction of American Geophysical Union, in press, 1983.
9. Hung, R. J., and Smith, R. E., Computer image processing of up-draft flow motion and severe storm formation observed from satellite, Proceedings on Flow Visualization, in press, 1983.
10. Hung, R. J., and Smith, R. E., Rapid-scan remote sensing of multiple tornadoes, Remote Sensing for Climate Studies, in press, 1983.

SEARCH FOR SOLAR SIGNALS IN GOES IMAGERY AND CLOUD CLIMATOLOGY ANALYSIS

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Airborne Research Associates
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Weston, Massachusetts 02193
(617) 899-1834

Significant Accomplishments to Date in FY-83

This project was initiated in October 1982 after a pilot study had been conducted using hand positioned photocells and a prototype of the automated computer controlled image analysis system had been assembled. The initial efforts involved deciding on specific components to purchase within the limitations of the contract. Initially a relatively simple version of the system was assembled which will suffice to replicate the pilot study and for identifying problem areas. The system was physically constructed and tested during which time several previously unknown problems became apparent. These involved the position of the shutter mechanism at the time the video system takes a picture (into memory) and variations of light intensity (AC and DC) in the movie projector lamp associated with line voltage fluctuations. A circuit was designed to halt the shutter in a fully open position via computer command when the picture was being taken and a highly stabilized voltage source was provided for the lamp. Control programs and additional software have been written. A major problem we are currently working on involves the frame-by-frame exposure variations in the film strips. We are experimenting with several approaches to normalization of the entire data set. Another problem involves the non-uniformity of responses from individual pixels in the CID (charge injection device) array; a normalization scheme has been worked out to make the responses of each pixel uniform.

Focus of Current Research Activities

We plan on continuing development of the automated GOES image analysis system and starting the analysis of possible cloud variations relative to variable solar activity. The next step will be to replicate the initial pilot project with the new system. In the pilot project the films were hand edited and a reference photocell was hand positioned on each image on the apparent darkest area in order to normalize light intensity variations between images. Our objective is to have the automated system do at least as well and to define the limits of what can be accomplished by the system. Only when we are satisfied that the system is working up to its anticipated potential will we proceed with the analysis of spatial and temporal variations of cloudiness. In the near future we will be introducing the interactive aspects of the system including imaging of the picture in the computer memory and a high resolution hard copy printer.

Plans for FY-84

During FY-84 we will continue the search for solar signals and a cloud climatology analysis begun during the current year.

Recommendations for New Research

It is too early to make recommendations relative to this program. Once we start to have results it is likely that the findings will bring up questions that should be considered. For example, our initial pilot study showed a 20% diurnal variation of cloudiness in the intertropical convergence zone. The more detailed analysis to come will define seasonal and year-by-year variations in this pattern for both the Eastern and Western GOES satellites and we will be able to compare the Pacific ITCZ cloudiness variations with those in the Atlantic ITCZ. These changes should be of interest to global and synoptic scale modelers and may be useful in testing models. Similarly, if variations in deep convection are correlated with aspects of solar variability, it will be necessary to examine cloud electrification in trying to explain such an association. In this regard the already existing temporal and spatial variation of lightning from ground networks and anticipated future lightning mapper data would provide the data necessary to see if the convective clouds were electrified.

List of Publications since June 1982

Solar Modulation of Fair-Weather and Thunderstorm Electrification and a Proposed Program to Test an Atmospheric Electrical Sun-Weather Mechanism, to be published in Solar-Terrestrial Influences on Weather and Climate, B.M. McCormac, Editor, Reidel (1983).

Comments on Measurement of the Global Electrical Circuit and the Hy-Wire Potential Variations at Wallops Island, submitted to J. Geophys. Res., March 1983.

LIGHTNING RESEARCH

TITLE: Overview of the Atmospheric Electricity Research Program

INVESTIGATOR: H. J. Christian
ED43/Tel: (205) 453-2463
Atmospheric Sciences Division
Marshall Space Flight Center, AL 35812

SIGNIFICANT ACCOMPLISHMENTS FOR FY-83:

Details of accomplishments are described in individual papers; this overview presents program status and overall progress.

Of major importance are the sensor feasibility studies conducted by TRW and Hughes Aircraft. Using the U-2 lightning data to form the design criteria, they have investigated a number of innovative ideas using mosaic array detectors and focal plane processing techniques that can be optimized for the detection of lightning from space. Status reports were presented during the second week of May, and final reports are due in June.

Results from analysis of U-2 lightning data have placed the sensor development portion of the program on a solid, quantitative basis. There exists sufficient lightning characterization data to proceed with prototype development for U-2 and other operations. The sensor development issues are basically technological at this stage.

Scientific applications of the lightning mapper have also been addressed and published. In addition, a number of ongoing research projects seek to understand relationships between lightning activity and storm dynamics. Some results from these studies are presented in following papers. The major emphasis has been to analyze lightning data in conjunction with other data sets, such as doppler radar, GOES images, cloud top heights, updraft velocities, rainfall rates, and so on. Limitations have included the lack of lightning data over large geographical areas. This type problem will be reduced when data from ground-based lightning networks are properly archived and made available for scientific research; however, it will not be eliminated until full disk coverage is available.

Our present lightning remote sensing systems use RF techniques. They include ground strike location networks positioned in the Western United States, along the Eastern Coast, at NSSL, etc., dual-based phase linear interferometers (San Antonio, TX, and MSFC), and a dual ELF system (NSSL and MSFC). These systems

hold the potential of providing good geographical coverage for the study of lightning activity in large storm systems.

In addition to studies of mesoscale lightning activity, work has continued on fundamental lightning physics using both RF and optical techniques. Absolute spectral irradiance measurements of both cloud to ground and intercloud flashes have been made as well as estimates of total flash power.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The spring U-2 field program is the major current activity. Attempts are being made to fully coordinate the multiple sensing systems which should include the NASA U-2, NSSL atmospheric electricity sensors, dual doppler radars, Storm Intercept (U. of Miss), RF sensors (NMIMT), phase linear interferometers (SWRI and MSFC), ELF system (NSSL and MSFC), rapid scan GOES (NOAA), an acoustic thunder array (Rice) and balloon borne electric field sensors (Rice and U. of Miss).

PLANS FOR FY-84:

The development of a brass board lightning mapper-like sensor will be a prime focus for FY-84. In addition, it is expected that major efforts will be expended in analyzing data acquired during the spring field program, and it is anticipated that exciting data from the BLM and East Coast networks will be available for the study of lightning activity in mesoscale storm systems.

Participation in TRIP-84 at the National Severe Storms Laboratory is in the planning stage.

PUBLICATIONS FY-83:

Christian, H. J., R. L. Frost, P. H. Gillaspy, S. J. Goodman, O. H. Vaughan, M. Brook, B. Vonnegut and R. E. Orville, 1983: Observations of Optical Lightning Emissions from above Thunderstorms Using U-2 Aircraft. Bulletin of the American Meteorological Society, 64, 120-123.

Davis, M. H., M. Brook, H. Christian, B. G. Heikes, R. E. Orville, C. G. Park, R. G. Roble and B. Vonnegut, 1983: Some Scientific Objectives of a Satellite-borne Lightning Mapper. Bulletin of the American Meteorological Society, 64, 114-119.

Goodman, S. J. and H. J. Christian, 1982: Airborne Measurements of Lightning Generated Optical Emissions, EOS, Vol. 63, No. 45, p. 889.

Weber, M. E., H. J. Christian, A. A. Few, and M. F. Stewart,
1982: A Thundercloud Electric Field Sounding: Charge
Distribution and Lightning, Journal of Geophysical Research,
87, C9, 7158-7169.

Christian, H., L. Lillie, C. P. R. Saunders and J. Hallett,
1983: Laboratory and Field Observations Related to Ice
Particle and Aircraft Charging in Convective Storms, to be
published in proceedings of International Conference on Lightning
and Static Electricity.

TITLE: SEVERE STORM ELECTRICITY

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SIGNIFICANT ACCOMPLISHMENTS FY 82:

Since October, our major emphasis has been on data reduction and analysis. This has included:

- 1) providing the locations of cloud-to-ground (CG) flashes during the 82 U2 overflights for combination with satellite and other data at MSFC.
- 2) detailed analysis of several positive CG (+CG) flashes to determine more specifically their physical characteristics.
- 3) determination of diurnal variation of +CG for July 82 where we found that the ratio of +CG/CG flashes peaks about 4 hours later (at 2230 CST) than the peak at 1830 CST for CG flashes of both polarities.
- 4) an analysis of CG flashes in tornadic storms, which indicates that there is no obvious minimum in CG flash activity in the storm as a whole during the time of tornadoes. The fraction of CG flashes that lower positive charge is larger before and during the tornado, and the number of strokes per flash increases after the tornadic stage ends. Within 10 km of the mesocyclone, the CG flashing rate increases as the mesocyclone weakens; the pattern in +CG flashes and number of strokes remains the same.
- 5) identification of CG flashes with an omnidirectional, long-range ELF (extremely low frequency) system. Analysis of ELF data is helping provide CG verification for +CG flashes, CG flashes beneath the U2, CG flashing rates in severe storms, etc.
- 6) Continuation of analysis of lightning activity and location relative to storm development and dynamics as determined with dual-Doppler radar.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

We are currently involved in preparation for the Spring 83 research program to be conducted from May 16-June 10. A significant part of this program will be data collection at NSSL and with the University of Mississippi/NSSL mobile laboratory during the U2 overflights. Immediately following the program, we plan to meet with MSFC personnel to determine what data are to be analyzed.

PLANS FOR FY 84:

We anticipate continued emphasis on analysis of data obtained during the U2 overflights and the coordinated study of lightning and storm structure. We anticipate that additional data on tornadic storms and intense squall lines will be obtained. These data will be examined for correlations between the characteristics of lightning activity and storm dynamics and severity, with a major goal being to ascertain where any of these are detectable from satellites and how that can increase forecast or warning capabilities.

PUBLICATIONS SINCE JUNE 1982:

Refereed

"Radar observations of thunderstorms", W. David Rust and Richard J. Doviak. Invited Review, Nature, 297, 461-468, 1982.

"Doppler radar echoes of lightning and precipitation at vertical incidence", Dusan S. Zrnic, W. David Rust, and William L. Taylor. J. Geophys. Res., 87, 7179-7191, 1982.

"Lightning propagation and flash density in squall lines as determined with radar", Vladislav Mazur and W. David Rust. J. Geophys. Res., 88, 1495-1502, 1983.

Unrefereed

American Geophysical Union Fall Meeting (abstracts in EOS, 63, 1982).

"Lightning detection and flash type identification using extremely low frequencies", William L. Taylor, W. David Rust, Donald R. MacGorman.

"Cloud-to-ground lightning in storms on the Great Plains", D. R. MacGorman, W. D. Rust, and W. L. Taylor.

"Measurements of positive cloud-to-ground lightning in Oklahoma", W. David Rust, William L. Taylor, and Donald R. MacGorman.

"Distribution of lightning flashes in thunderstorms from observations with UHF- and S-band radars", Vladislav Mazur, John Gerlach, and W. David Rust.

Severe Storm Electricity: Storm Intercept

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To date in FY-83, we have prepared the mobile laboratory for use in the field in the spring of 1983 in support of the U-2 overflights, and we have completed our first case study of a storm that occurred in the Texas panhandle on 19 June 1980. The results were reported at the FY-82 Atmospheric Processes Research Review and have been submitted for publication.

Currently, our efforts (aside from preparation for support of the U-2) are concentrated on the four problems listed below. Data for the analyses were acquired on 17 May 1981

1. Analysis of corona currents, electric fields, and lightning electric field changes near mesocyclones is now the focus of our work on past data. Measurement of these quantities will be of central importance in data acquisition for 1983.
2. Documentation of lightning and storm structure is an important part of our analysis. From the mobile lab, we were in an ideal position within NSSL's Doppler radar network to observe both lightning and evolving storm structures. We are searching for correlations between dynamics as determined by radar and electricity as determined both from the mobile lab and NSSL's fixed base electricity network.
3. Use of field changes from two stations to estimate the height from which single stroke lightning originates within a mesocyclone.
4. Verification of both the accuracy and the efficiency of NSSL's LLP system over a major portion of the dual Doppler radar network.

During the summer of 1983, we expect to concentrate our efforts of data obtained in support of U-2 overflights. In particular, we will document optical transients and electric field changes for both daytime and nighttime U-2 flights.

Many of the electrical and dynamical correlations are undoubtedly subtle, but we have little doubt that the dynamics and/or thermodynamics drive a storm's electricity. If in the future we are to use satellite data to forewarn of severe storms, then we would profit by making more observations near a storm's main updraft/downdraft couplet during the formative and vigorous stages. Spatial and temporal Doppler radar resolution better than

can be provided by existing radars might be required; in particular, a mobile radar operating within a storm's updraft would be most useful.

Publications: (No publications have been published. The following papers have been submitted)

1. "A Study of Severe Storm Electricity via Storm Intercept," Roy T. Arnold, W. David Rust, and Don Burgess (submitted to JGR).
2. "Quasistatic Electric Fields Beneath Mesocyclones," Roy T. Arnold and W. David Rust (submitted to the Thirteenth Conference on Severe Convective Storms).
3. "Cloud-To-Ground Lightning in the Mesocyclone Region of Severe Storms," Steve Horsburgh, Roy T. Arnold, and W. David Rust.

Summary of Research Activities

TITLE: Remote Observations of Severe Storms

Research Investigators: Richard E. Orville
and

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Significant Accomplishments to Date in FY-83:

Absolute spectral irradiance measurements of lightning have been made from 300 nm to 880 nm. These studies indicate that lightning can be detected in daytime conditions if emission lines in the near-infrared are observed with appropriate solid state detectors. One molecular emission has also been observed that may be an indicator of the presence of a lightning continuing current, known to be a cause of forest fire.

Our global lightning data base of over 32,000 flashes has been compared, at the suggestion of James Dodge, with a Japanese study of global lightning that has recently been published. The Japanese report is based on a radio based satellite system with approximately 10 degree resolution as compared to our analyses using the DMSP optical system with 1 degree resolution. After expanding our plots to 10 degree resolution and using only the Japanese midnight data, we find excellent agreement between the two satellite systems in their recording of global lightning locations. This agreement suggests that we may be able to extrapolate our midnight DMSP data to estimate the distribution of daytime lightning.

An East Coast lightning location system for research has been established that detects most ground flashes from Maine to North Carolina and as far west as Ohio. Location, time, polarity, multiplicity, and peak magnetic field are recorded in real time and displayed on several CRT monitors

for analyses. In addition, a McIDAS terminal for the processing of satellite images has been installed in the same room at SUNY-Albany that displays the lightning data. This provides for near real-time interpretation of the lightning data in a severe storm with the associated meteorological characteristics available from satellite imagery. We have successfully operated our network throughout the winter and have seen significant lightning activity in every week. Polarity, multiplicity, peak magnetic field, and location all show variations in winter storms that, at the moment, are a puzzle to us.

Focus of Current Research Activities:

We are analyzing and preparing manuscripts on our spectral irradiance studies and our global lightning results. In addition, we are attempting to understand the numerous research questions that have developed from operating a large lightning location system throughout the year along a coastal region of a major continent.

Plans for FY-84:

We hope to work closely with the Marshall Space Flight Center scientists in obtaining and interpreting U-2 aircraft data from overflights of thunderstorms.

List of Publications since June 1982:

Davis, M.H., M. Brook, H. Christian, D.G. Heikes, R.E. Orville, C.G. Park, R.G. Roble, and B. Vonnegut, 1983: Some scientific objectives of a satellite-borne lightning mapper. **Bulletin of the American Meteorological Society**, 64, 114-119.

Christian, H.J., R.L. Frost, P. H. Gillaspy, S.J. Goodman, O.H. Vaughan, Jr., M. Brook, B. Vonnegut and R.E. Orville, 1983: Observations of optical lightning emissions from above thunderstorms using U-2 aircraft. **Bulletin of the American Meteorological Society**, 64, 120-123.

Levine, J.S., G.L. Gregory, G.A. Harvey, W.E. Howell, W.J. Borucki, and R.E. Orville, 1982: Production of nitric oxide by lightning on Venus. **Geophysical Research Letters**, 9, 893-896.

Orville, R.E., and V.P. Idone, 1982: Lightning Leader Characteristics in the Thunderstorm Research International Program (TRIP). **Journal of Geophysical Research**, **87**, 11,177-11,192.

Orville, R.E., R.W. Henderson, and L.F. Bosart, 1983: An East Coast Lightning Detection Network. **Fifth Symposium on Meteorological Observations and Instrumentation**, April 11-15, 1983. Toronto, Ont., Canada. 520-525.

Henderson, R.W., and R.E. Orville, 1982: Absolute spectral irradiance measurements of lightning return strokes from 375 nm to 880 nm, (abstract) **EOS (Transactions American Geophysical Union)**, **63**, 45, 890. Presented at the Fall Annual Meeting of the American Geophysical Union, San Francisco, California, December, 1982.

Orville, R.E., and R.W. Henderson, 1982: Global distribution of midnight lightning from September 1977 to August 1978. (abstract) **EOS (Transactions American Geophysical Union)**, **63**, 889. Presented at the Fall Annual Meeting of the American Geophysical Union, San Francisco, California, December 1982.

Idone, V.P., and R.W. Henderson, 1982: An Unusual Lightning Ground Strike, **Weatherwise**, **October**, 1982, 223-224.

TITLE: STORM SEVERITY DETECTION (RF)

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SIGNIFICANT ACCOMPLISHMENTS TO DATE:

The objective of this program has been to develop severe storm discrimination techniques applicable to space-borne optical/electromagnetic atmospheric electricity sensors. Effort on this project has been in progress for four years. A technical review of significant accomplishments to date includes:

(1) Under first year funding, a crossed baseline interferometer was operated at San Antonio, Texas. The objective of the effort was to determine the extent to which HF sferic activity could be used to discriminate meteorologically severe storms from non-severe storms. During this period, computer software was developed to provide automatic unmanned data acquisition.

(2) Second year funding provided for the monitoring of electrical activity associated with continental thunderstorms as well as tropical storm activity occurring in the Gulf of Mexico. Analysis of data acquired during this period yielded the following results: (a) the data exhibited the first known capability for severe storm discrimination over multi-state regions using directionally resolved sferic burst counts; (b) the phase linear interferometer was capable of severe storm discrimination to ranges of 2000 km.

(3) Third year funding provided for continued data acquisition and analysis. The focal point of the data analysis was hurricane activity which had occurred in the Gulf of Mexico during 1979 and 1980. The analysis produced the following observations: (a) of the three hurricanes which organized within the detection range of the direction finder, there was no evidence of a significant degree of electrical activity such as is routinely observed in deep convective continental thunderstorms; (b) there appears to be a significant enhancement of atmospheric electrical activity associated with the inland movement of the storm. The data indicate a precursor sferic buildup of approximately six to twelve hours prior to landfall; (c) tornadic activity which was formed in association with hurricanes BOB, FREDERIC and ALLEN did not produce an intensification of electrical activity corresponding to that observed in tornadic continental thunderstorms.

(4) Program efforts during the fourth year were directed toward the fabrication and deployment of a phase linear interferometer at MSFC equivalent to the SwRI instrument. Deployment of this direction finder permitted measurement of angles of arrival and estimation of spheric location by triangulation. Both direction finders were operated during the 1982 storm season. Analysis of data acquired during this period has resulted in: (a) the development of location software and the mechanism for inclusion of these data into the McIDAS data base; (b) the incorporation of a remote terminal at MSFC and a refinement of the experimental design for data acquisition.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Simultaneous data acquisition is currently in progress to monitor continental thunderstorm activity occurring throughout the central and south eastern United States. Electrical events are time coded at each site using a WWV satellite receiver. The data are recorded on 5 MByte removable disk cartridge and archived on magnetic tape.

PLANS FOR FY-84:

The data obtained during the 1983 storm season from both sites will be processed for time correlated events. The intersection of simultaneous bearing estimates will be used to estimate the location of spheric activity. The position data will be formatted in latitude and longitude for entry into the McIDAS meteorological data base.

The lightning location data will be analyzed as a function of storm severity and evolution.

RECOMMENDATIONS FOR NEW RESEARCH:

Based upon the results obtained to date, the following are recommended initiatives:

1. Investigate the electrical signature present when the phase linear criteria are satisfied to determine the breakdown processes which emit planewave atmospherics.
2. Analyze the electrical signature for the 14 millisecond data acquisition period to obtain evidence of the electrical discharge process which appears to be most indicative of meteorological intensity.

TITLE: Status Report of Research Activities, FY-83

Investigator: Dr. Phillip H. Gillaspay
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Significant Accomplishments:

A paper was prepared and presented at the annual Fall Meeting of the American Geophysical Union in December of 1982. The results of analyzing data from Optical Pulse Sensor measurements were discussed. Also, preliminary results of spectrometer measurements were discussed. Among the data presented were histograms of radiant energy per pulse, radiant power per pulse, peak energy pulse per flash event, interpulse interval, pulse half-width, pulse risetimes. That these data are crucial to the design of a satellite based lightning sensor was pointed out to conference attendees. The same set of data was presented to the two aerospace companies, TRW and Hughes Aircraft, who are presently performing a feasibility study of a satellite based lightning sensor mapper.

Optical Pulse Sensor data was prepared for Dr. Hugh Christian, Lightning Research Program Team Leader, who presented a review of the lightning measurements to date to Dr. Shelby Tilford, NASA Environmental Observations Program Director.

Focus of Current Research:

Preparations are under way for the spring 1983 field program to be conducted the last 2 weeks of May. These activities are the reconfiguration of some electronics for the 1/8 and 1/2 meter spectrometers, the addition of noise filter circuits, reprogramming PCM microprocessor module and modifications to PCM circuitry, and finally standard checkout of instrument operation.

Plans for FY-84:

The spring 1983 field program should be the most productive yet and will require considerable time just to perform the basic analysis of optical pulse data. Subsequently analysis will begin on spectrometer data and Optical Array Sensor data. It is anticipated that a rather large paper or several papers will be prepared for publication to the Journal of Geophysical Research. Results will also be presented at the annual Fall Meeting of the American Geophysical Union.

Publications FY-83:

"Observations of Optical Lightning Emissions from above Thunderstorms Using U-2 Aircraft." H. J. Christian, R. L. Frost, P. H. Gillaspy, S. J. Goodman, O. H. Vaughan, Jr., M. Brook, B. Vonnegut, and R. E. Orville, 1983: Bull. Am. Meteorol. Soc., 64, 120-123.

"Lightning Statistics from U-2 Research." P. H. Gillaspy, 1982: Proceedings of the American Geophysical Union Fall Meeting, San Francisco, CA.

TITLE: PANEL --

SCIENTIFIC OBJECTIVES OF A SATELLITE-BORNE LIGHTNING MAPPER

Sponsored by Contract NAS8-33730: Research Study: Studies in Atmospheric Processes from Space Platforms.

Project Director: Dr. M. H. Davis

USRA

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In May, 1982, USRA assembled a panel of experts in atmospheric electricity and related fields to identify the scientific research areas that can be expected to benefit from the Satellite-borne Lightning Mapper that is under development, and to specify the requirements that science places on the system. Research specialties included were: Magnetospheric and Ionospheric Physics, Chung G. Park; The Global Electric Circuit, Raymond G. Roble; Thunderstorm Studies, Bernard Vonnegut; Cloud Physics, Marx Brook; Atmospheric Chemistry, Brian G. Heikes; Lightning Studies, Richard E. Orville; Atmospheric Electricity, John Latham; Sun-Troposphere Coupling, M. H. Davis. NASA/MSFC representative was Hugh Christian.

The panel concluded that each of these research areas stands to benefit significantly from data produced by the satellite-borne lightning mapper sensor. A summary paper was prepared which has now been published:

M.H. Davis, et al., "Some Scientific Objectives of a Satellite-Borne Lightning Mapper", Bull. Am. Met. Soc., Vol. 64, No. 2, February, 1983.

Title: Space Shuttle Observations of Lightning (NOSL)

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Significant Accomplishments:

16 mm film and cassette recordings of photocell signals taken with the NOSL equipment on STS-2 and STS-4 have been analyzed. Daytime photographs taken on both missions showed interesting convective cloud structures. At night-time photographs of distant lightning discharges, probably over Africa, were obtained on STS-2. On STS-4 interesting 16 mm sequences taken at 24 frames per second showed lightning discharges that continued to grow and spread at speeds of the order of 10^5 meters per second at distances of 60 kilometers or more. In one case two apparently almost simultaneous discharges were observed to originate on a frame with a separation of 80 kilometers or more. With the limited amount of data obtained thus far, it is difficult to know whether there may be some relation between the two widely separated discharges or whether their occurrence was purely fortuitous.

Preliminary examination of the photographic film obtained on STS-6 shows several interesting convective systems in severe storms over the Gulf states taken during the daytime and lightning sequences taken during the night. Although the lightning photographs are less frequent and of shorter duration and smaller dimensions than those taken on STS-4, the most recent photographs show new features not seen in the first two missions.

In contrast to the illuminated areas observed on STS-4, which ranged in color from yellow to deep red, the discharges on STS-6 showed various colorations in the same frame varying from red through white to blue. In contrast to the earlier lightning photographs, which revealed no details of cloud structure, those obtained on STS-6 show clearly recognizable cumuliform structures that repeatedly occur in a lightning sequence. These structures provide fiducial points for analysis that have not previously been available.

Because the cassette tapes of the photocell signals obtained on STS-6 have not been analyzed at the time of this writing, no information is yet available on whether any photo-optical signatures of lightning were obtained.

Plans for FY 83:

The photographs and cassette tapes taken on STS-6 will be analyzed. Improved equipment will be devised for possible future shuttle flights.

List of Publications:

Vonnegut, B., 1982: Top weather event of 1981--Flight of the space shuttle. **Weatherwise** 35, 1, p 27.

Vonnegut, B., O. H. Vaughan, Jr., and M. Brook, 1983: Photographs of lightning from the space shuttle. **Bull. Amer. Meteorol. Soc.** 64, 2, pp 150-151.

APPENDIX A

NASA/MSFC FY83 "DELTA"
ATMOSPHERIC PROCESSES RESEARCH REVIEW
May 24-25, 1983
Building 4481/Room 515
Marshall Space Flight Center, AL 35812

Tuesday, May 24, 1983

0830-0845 a.m.	Introduction and Overview	William W. Vaughan
0845-1200 a.m.	Global Scale Processes Research Overview	George H. Fichtl
	o Satellite Data Analysis	
	o General Fluid Flow Cell Experiment and Associated Research	
	o Supporting Research for Atmospheric General Circulation Experiment	
1200-0100	Lunch	
0100-0430 p.m.	Doppler Lidar Wind Research Overview	Daniel E. Fitzjarrald
	0 Airborne/Ground Base Doppler Lidar Research	
	o 1981 Flight Experiments Data Analysis/Research	
	o 1982 Ground Tests and Experiments	
	o 1984/85 Flight Experiment Program Plans	
	o 1983/84 Ground Experiment Plans	
	0 Satellite Wind Profiler Research	
	o Backscatter Meeting Assessment	
	o Backscatter Data Analysis and Plans	
	o Simulation Research Status and Plans	
	o Research Proposal Status Discussion	

NOTE: "DELTA" Review on Accomplishments Since October 1982 Review.
Individual Topic Speakers TBD.

Wednesday, May 25, 1983

0830-1200 a.m.	0 Mesoscale Research Program Overview	Gregory Wilson
	o Supporting Research and Technology Development (Summary)	
	o The Mesoscale Environment (Summary)	
	o Clouds/Precipitation (Summary)	
	o Mesoscale Environment - Clouds/Precipitation Interactions (Summary)	
1200-0100 p.m.	Lunch	
0100-0200 p.m.	0 Solar-Lower/Upper Atmospheric Coupling Research	Robert Smith
0200-0400 p.m.	0 Lightning Research Program Overview	Robert Smith
	o Discussion on Selected Lightning Mapper Research Activities	
	o Supporting Research	
	o U-2 Flight Program Status	
	o Lightning Mapper Sensor Status	
	o NOSL	
0400-0430 p.m.	0 Overall Research Program Discussion	William W. Vaughan James C. Dodge Robert H. Curran John S. Theon

APPENDIX B

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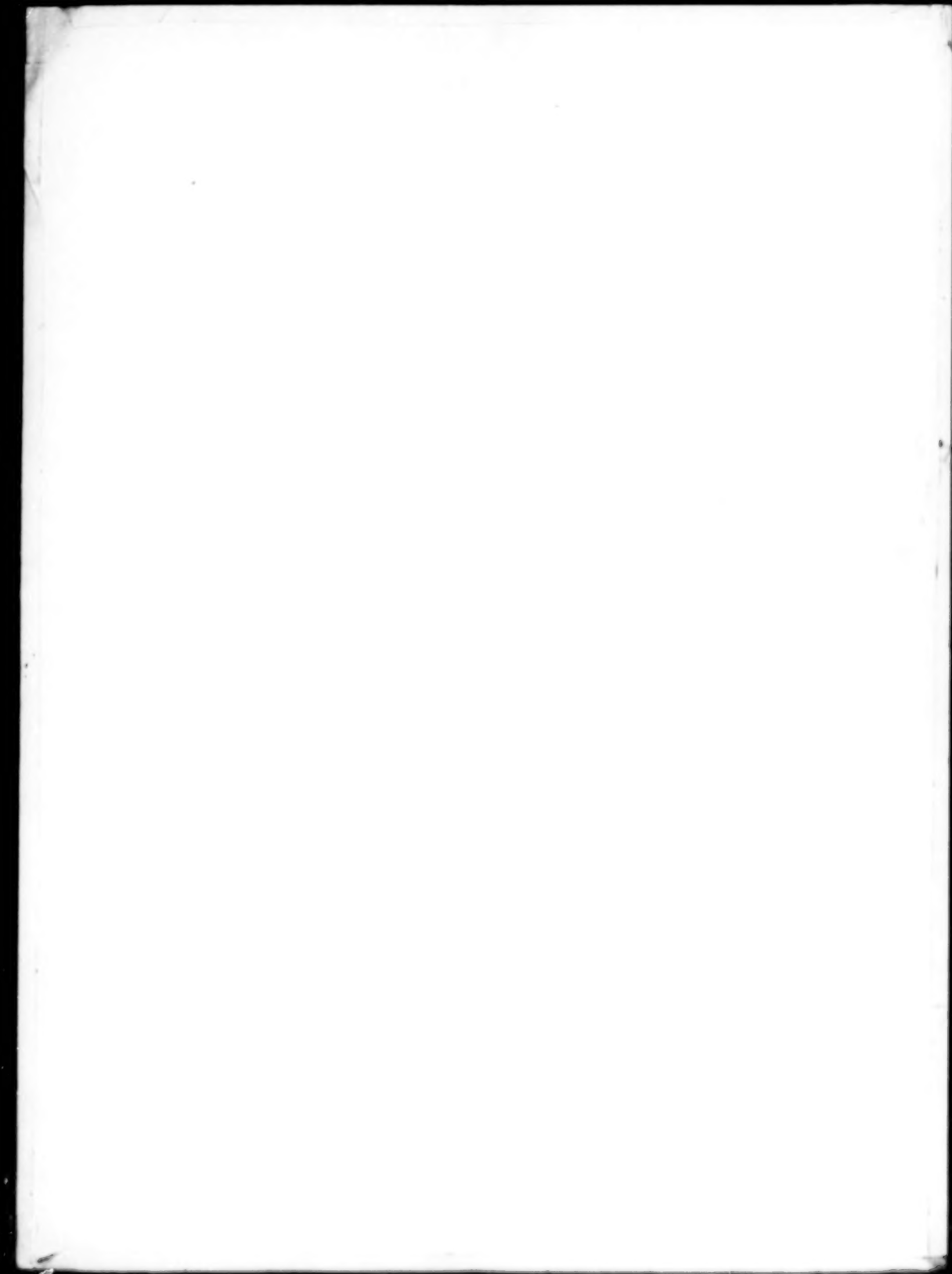
APPENDIX C

Organizations Whose Sponsored Research Efforts
Are Included In The
FY-83 Atmospheric Processes Research Review

Airborne Research Associates
Alabama A&M University
Atsuko Computing International
Battelle Pacific Northwest Laboratories
City University of New York
Drake University
Drexel University
General Electric
Lassen Research, Inc.
Los Alamos National Laboratories
Marshall Space Flight Center Information and Electronics
Systems Laboratory
Marshall Space Flight Center Space Science Laboratory
Marshall Space Flight Center Systems Dynamics Laboratory
Massachusetts Institute of Technology
National Earth Satellite Service, NOAA
National Severe Storms Laboratory, NOAA
New Mexico Institute of Mining and Technology
Pennsylvania State University
Purdue University
Saint Louis University
Science Applications, Inc.
Space Environment Laboratory, NOAA

Southwest Research Institute
State University of New York at Albany
Texas A&M University
The University of Alabama in Huntsville
The University of Arizona
University of California, Davis
University of Chicago
University of Colorado
University of Illinois
University of Miami
University of Mississippi
University of Oklahoma
Universities Space Research Association
University of Tennessee, Tullahoma
University of Utah
University of Wisconsin, Madison
University of Washington
Yale University
U. S. Geological Survey

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